

Reports from the Conference of the Swedish National Committee for Physics in 1957

By GUDMUND BORELIUS and ERIK RUDBERG

The Swedish National Committee held its 9th General Physics Conference on June 3-5, 1957 at the University of Uppsala. The Department of Physics had generously shouldered the task to serve as host to the meeting. The large number of contributed papers made it necessary to run as many as three discussion sections in parallel for part of the time. While such an arrangement renders it impossible for an individual to attend all discussions, the inconvenience can be reduced by a good choice of grouping for the presentations. Easy intercommunication between the different conference rooms is then highly desired. Additional space for the parallel sessions was provided by the Department of Chemistry, which very kindly placed a lecture room at the Committee's disposal. Clearly, most of the time had to be devoted to presentation of papers and to the ensuing discussions. In addition, the participants had the good fortune of receiving an invitation to the Gustaf Werner Institute for Nuclear Chemistry, where the synchrocyclotron and adjoining laboratories were shown. The various research projects now in progress in the Department of Physics at Uppsala and the new addition to the institute buildings were also demonstrated. A visit was arranged to the Ionosphere Laboratory, erected at Lurbo by the Research Institute of National Defence.

The National Committee for Physics had the pleasure to welcome to this conference several distinguished scientists from other countries. Special guest lectures were given by M. A. Melvin of Florida State University who spoke on "Conservation—invariance principles and the behaviour of elementary particles", and by H. Palevsky from Brookhaven National Laboratory who discussed "The use of cold neutrons to investigate the solid state." Short summaries of the other papers presented at Uppsala are included in the remainder of this report.

Dr. Å. Nilsson of the Physics Department of Uppsala served as the Secretary of the Conference and shared with the hosts, Prof. P. Ohlin and Prof. K. Siegbahn, the responsibility for the success of the meeting.

KATARINA AHNLUND, *Nobel Institute of Physics, Stockholm*

Angular distribution measurements of (d,p)-reactions I

Deuterons from the Nobel Institute Cockcroft-Walton accelerator have been used to bombard thin targets of some light elements. The angular distributions of proton

groups from the targets have been analysed by the rotatable alpha spectrometer and detected in nuclear emulsion plates. As the intensity of a particle group ejected in any direction has to be related to the intensity of the same group in some fixed direction a complete angular distribution measurement for one bombarding energy and for every 7.5° between 0° and 135° involves the exposure of at least some 40 plates.

The special advantage with our experimental set-up is the high energy resolution, which permits a study of angular distributions of particle groups with small energy difference as in the actual cases of $B^{10}(d,p)B^{11}$, $N^{14}(d,p)N^{15}$ and $O^{18}(d,p)O^{19}$.

KATARINA AHNLUND, *Nobel Institute of Physics, Stockholm*

New energy levels in F^{18} from the $O^{17}(p,\alpha^1)N^{14}$ -reaction

A separated isotopic target of O^{17} , prepared in Stockholm, was used with the 3 MeV electrostatic accelerator and double-focusing alpha-spectrometer of Kellogg Radiation Laboratory, California Insititute of Technology, Pasadena, U.S.A. The reaction $O^{17}(p,\alpha)N^{14}$ had not been observed earlier due to difficulties to obtain enriched O^{17} . The excitation function of ground state alpha particles from this reaction was studied for proton energies between 1 and 3 MeV and it showed thirteen resonances corresponding to excited levels in the compound nucleus F^{18} .

H. ALFVÉN, *Department of Electronics, Royal Institute of Technology, Stockholm*

Magneto-hydrodynamic waves in the atomic nucleus

Hydrodynamic models are important for the understanding of some properties of the atomic nucleus. As the nucleus has a magnetic moment, hydrodynamic phenomena should be affected by a magnetic field. Hence the classical analogy should not be ordinary hydrodynamics but instead magneto-hydrodynamics. It is of interest to calculate the order of magnitude of possible magneto-hydrodynamic resonance frequencies. The electric conductivity is assumed to be infinite.

The magneto-hydrodynamic velocity V_{MH} is

$$V_{MH} = H(4\pi\rho)^{-1/2}$$

where H is the magnetic field and ρ the density. Suppose that a nucleus with radius r has a uniform magnetization giving a magnetic moment of B nuclear magnetons. The magnetic field inside the nucleus is

$$H = 2B\mu_0 r^{-3}$$

where $\mu_0 = eh(4\pi M_p c)^{-1} = 5 \cdot 10^{-24}$ gauss cm^3 , and $r = r_0 A^{1/3}$, with $r_0 = 1.5 \cdot 10^{-13}$ cm. (A = atomic weight, M_p mass of a nucleon). As the density is $\rho = A M_p (\frac{4}{3}\pi r^3)^{-1} = \frac{3}{4\pi} M_p r_0^{-3} = 10^{14}$ g cm^{-3} we get

$$V_{MH} = \frac{B}{A\sqrt{3}} \frac{eh}{2\pi c M_p^{3/2} r_0^{3/2}} = \frac{B}{A} \cdot 8 \cdot 10^7 \text{ cm s}^{-1}.$$

One of the lowest modes of oscillation is a torsional standing wave along the magnetic axis. The wavelength is somewhat smaller than $4r$, which means a frequency $\nu = V_{MH}(4r)^{-1}$. This corresponds to an energy $W = h\nu = C W_{MH}$

where

$$W_{MH} = \frac{e\hbar^2}{c M_p^{3/2} r_0^{5/2}} = 10^{-6} \text{ erg} = 0.5 \text{ MeV}$$

and

$$C = \frac{\pi}{2\sqrt{3}} \frac{B}{A^{4/3}}$$

R. ALPHONCE, A. JOHANSSON, and G. TIBELL, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Asymmetry in elastic and inelastic scattering of polarized protons on light nuclei

The asymmetry of 155 MeV protons scattered elastically and inelastically (first excited level) from carbon, oxygen and calcium has been studied with the conventional double-scattering technique. The levels, 4.4 MeV in carbon, 6.1 MeV in oxygen, and 3.7 MeV in calcium, are highly excited and well separated from other levels. The energy spread of the protons was small enough to allow separation between elastically and inelastically scattered particles by absorbers in a range telescope. The elastic asymmetries show a characteristic angular pattern, which is quite similar for the three elements in the region studied (2° – 35°). The inelastic asymmetry of carbon is positive and rather high between 16° and 35° ; for oxygen and calcium only qualitative results have been obtained.

T. ALVÄGER and G. OELSNER, *Nobel Institute of Physics, Stockholm*

On the systematics of transition probabilities of M 4 transition of the type $h_{11/2}$ – $d_{3/2}$

A careful analysis is made of the radial matrix elements of M 4 transitions of the type $h_{11/2}$ – $d_{3/2}$. It has previously been claimed that the matrix elements systematically increase towards the magic numbers. Especially the matrix element of Te^{133m} was found to be large in comparison with the matrix elements of the other tellurium isomers. For this reason the decay of Te^{133m} has been studied. The half-life of the isomeric state was found to be 53 ± 4 m with a decay energy of 334.0 ± 0.3 keV. Further a large β -branching of 87 % from the isomeric level was found. This reduces the empirical matrix element of Te^{133m} to the order of magnitude of the other matrix elements in the isomer of tellurium. It must therefore be concluded that there are no certain experimental proofs that the matrix elements of M 4 transitions are larger when shells are almost filled.

G. ANDERSSON and I. BERGSTRÖM, *Nobel Institute of Physics, Stockholm*

Nuclear shell evidence and systematics of energy levels and multipole transitions in the lead region

A compilation has been made of experimental data concerning energy levels of nuclei in the Z-region 76–84. The data include spin, parity and half-life of the levels as well as energy and conversion ratios of the multipole transitions involved in their

de-excitation. Regularities in level separations are pointed out and the appearance of certain levels is discussed on the basis of single-particle and many-particle shell model predictions. A comparison is made between experimentally determined γ transition probabilities for E2, E3, E4, E5, and M4 transitions and those calculated from single-particle theory. K/L and $(L_I + L_{II})/L_{III}$ conversion ratios are found to agree reasonably well with the values obtained from Rose's tables.

I. ANDERSSON, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Absolute measurements of tritium in water

Tritium is formed, when heavy water is exposed to neutrons, and it was to make a check on the tritium content in the moderator in the R 1-reactor that these measurements were done.

Tritium is a β -active isotope with $E_{\beta\text{-max}} = 18$ keV and $T_{1/2} = 12.4$ years. The low energy of the radiation makes it necessary to use special methods for its registration. We have used internal gas counting with GM-counters. The tritiated water sample is brought into contact with calcium carbide, and in the reaction active acetylene gas is formed. The acetylene mixed with argon, is then used as *filling* gas in a GM-counter combination, consisting of two cylindrical tubes of the same construction but with different lengths. The end effects can thus be eliminated and the number of disintegrations per volume can be determined. The accuracy is about 1 %. If the acetylene pressure in the GM-tubes is known, the tritium content in the water sample can be calculated.

Results: The tritium activity in the heavy water in R 1 was on Oct. 20th, 1956, 3.50 ± 0.04 $\mu\text{c/g D}_2\text{O}$. (The international maximum tolerance dose for continuous exposure of tritiated water is 0.2 $\mu\text{c/g D}_2\text{O}$).

This method of measuring tritium has also been used for a determination of the activation cross section σ_{act} for the reaction between deuterium and thermal neutrons.

Results: $\sigma_{\text{act}} = 0.46 \pm 0.02$ mb for 2200 m/s neutrons.

E. ARBMAM, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Levels in Bi^{206} and Bi^{207} studied from the decays of Po^{206} and Po^{207}

Po^{206} and Po^{207} decay predominantly by electron capture to excited states in Bi^{206} and Bi^{207} respectively. Energies, intensities and multipolarities of the transitions in the Bi nuclei have been studied by the use of a double focusing β -ray spectrometer and a single channel pulse-height analyser. Coincidences between pairs of electron lines have been measured in a coincidence spectrometer. Based on the coincidence results and transition, energies and intensities decay schemes are constructed.

In Bi^{206} the energies of 9 excited levels have been established. The first level is de-excited by a 59.9 keV E2 transition. A half-life of 7.5 ± 0.5 μs . for this state has been measured by the use of a multichannel time analyser.

Po^{207} decays to a small extent by β^+ emission. The analysis of the β^+ -distribution reveals at least two β^+ -components. More than 30 gamma transitions in Bi^{207} have been observed. Some preliminary features of the level scheme of Bi^{207} will be given.

Parts of this work has been performed in co-operation with P. A. Tove, T. R. Gerholm and J. Burde.

S.-E. ARNELL, *Department of Physics, Chalmers Institute of Technology, Gothenburg*

Half-lives of the positron-emitting mirror nuclides

A plot of $\log \tau_{1/2}$ against $\log A^{2/3}$ is discussed in terms of shell effects in the charge distribution. It is shown that individual lines can be drawn through the data between successive closed proton subshells. Relatively longer half-lives occur from the points where the β^+ -transforming proton in the parent nucleus is just outside a closed proton shell. By comparing the data contained in such a line it can be assumed that the difference between the proton pairing energy and the neutron pairing energy must be small for the mirror nuclides.

INGER ASPLUND, *Department of Physics, University of Stockholm*

Angular correlation measurements on Eu^{153}

The angular correlation of the two most intense γ -rays in Eu^{153} following the β -decay of Sm^{153} has been measured. The γ -energies are 69 keV and 103 keV in the emission order. Liquid sources of $\text{Sm}(\text{NO}_3)_3$ dissolved in water as well as polycrystalline sources of Sm_2O_3 have been used. The anisotropy for solid sources is found to be slightly larger than for solutions. The possibility of perturbations is considered. The experimental value of A_2 in the expression $W(\theta) = 1 + A_2 P_2(\cos \theta)$ cannot be fitted to a theoretical one for any possible spin sequence with pure character of the γ -transitions. According to angular correlation results as well as conversion coefficient data and theoretical considerations the two γ -transitions could be of mixed M1-E2 character. A critical discussion of different possible decay schemes is given.

B. AXELSSON, O. BECKMAN and P. BERGVALL, *Department of Physics, University of Uppsala*

A 2.5-meter curved crystal X-ray spectrometer

The spectrometer is of the Du Mond type with a bent crystal mounted for transmission with a real source and a virtual image. The source is kept fixed, being a slit illuminated by the X-rays from the exchangeable target in the electron accelerating tube of a 800-kV electrostatic generator. The crystal is of quartz (1340 plane), size $25 \times 15 \times 1 \text{ mm}^3$, bent to a radius of 2.5 m. It can be rotated and the angle of rotation measured on a precision circular scale to within 0.1 second of an arc. The NaI scintillation detector is movable around the crystal and its position is controlled by an optical system. Preliminary measurements on $\text{W } K\alpha_1$ have yielded a signal to noise ratio of 60, a peak intensity of 500 counts/s and a line width at half maximum of 0.30 XU. The energy range covers the K -spectra from Ag to Pu. It is planned to use the instrument for gamma radiation also.

L. BECKMAN, *Research Institute of National Defence, Stockholm*

Investigation of a barium vacuum getter pump

A vacuum pump which utilizes the clean-up property of barium has been investigated. The quantity of barium used in the pump is about 120 g. The pumping speed

for different gases has been measured and found to decrease exponentially with the amount of gas absorbed. The pumping speed for the inert gases is extremely low and so an electric discharge of the Philips type is used to take care of these gases. (The investigation has been carried out at the High Voltage Research Laboratory at M.I.T., Cambridge, Mass., U.S.A. in collaboration with Dr. John G. Trump and Robert W. Cloud).

O. BECKMAN, *Department of Physics, University of Uppsala*

A photographic curved crystal gamma spectrometer

This transmission type spectrometer is designed for the wavelength region 250–60 XU (50–200 keV) using the 5052 plane of quartz. This plane has good reflecting properties and a small grating constant (810 XU), which gives large Bragg angles.

The gamma spectra are registered photographically on Ilford G5 emulsions of 100μ thickness, which have considerably higher sensitivity than ordinary X-ray film. It is possible to register the gamma lines by counting the electron tracks in the emulsion in a microscope. This method, though rather tedious, is more sensitive than the ordinary comparator method, and gives more information concerning the line intensities.

O. BECKMAN and R. SANDSTRÖM, *Department of Physics, University of Uppsala*

X-ray photo-excitation of Li^7

In earlier investigations on nuclear resonance scattering of photons one has used the gamma-rays from nuclei of the same kind as the scattering nuclei. In this case the energy loss due to the recoil has to be compensated by mechanical or thermal motion or in other ways.

In this investigation we have excited the nuclear levels by the continuous X-ray spectrum from a gold target bombarded with electrons of 640 keV energy. The scattered radiation from the Li-sample was registered at an azimuthal angle of 120° by a NaI-scintillation counter in connection with a hundred channel pulse height analyzer. The spectrum from the scintillation counter contains a small peak due to resonance scattering from the 477 keV level in Li^7 on an intense background resulting from coherent Rayleigh and Thomson scattering. The incoherent Compton-scattered radiation has an energy that is lower than 250 keV at the large scattering angle used.

The intensity of the resonant scattered radiation gives a width of $2 \cdot 10^{-3}$ keV for the 477 keV level in Li^7 , which corresponds to a half-life of $3 \cdot 10^{-13}$ s.

K. E. BERGKVIST, *Nobel Institute of Physics, Stockholm*

Possibilities of, and experiments on a combined electrostatic and magnetic β -spectrometer for high resolution spectrometry

In order to increase the luminosity, i.e. the product of the sample area and the transmission, of the two-directional focusing β -spectrometer two electrostatic devices may be added. One of them, situated intermediately between the sample and the detector acts as a "corrector" of the aperture defect, while the other consists of a

kind of electrostatic accelerator at the sample, which is made up by a number of narrow strips. The potentials of these vary with their radial positions in such a way that the resulting change of the energy of the electrons make the images of the different strips fall at the same radius at the detector. The possibility of combining the two devices is discussed and a possible way of making the corrector is given. Questions of energy dependence of the focusing properties of the whole system, of scattering and of requirements on voltage constancy of the electrostatic parts are considered. Some extremely preliminary results are given.

P. BERGVALL, O. BECKMAN and B. AXELSSON, *Department of Physics, University of Uppsala*

Correction to measurements of K absorption edges by crystal diffraction

From Cornell University has been reported¹ a distorting "thickness effect" in crystal diffraction measurements of absorption edges due to the shape of the spectral window and dependent on the thickness of the absorber. With the above described 2.5-meter spectrometer the energy position of the W K-absorption limit—as defined by the Cornell group—has been determined for 5 different absorber thicknesses, using the continuous spectrum from an U target. A shift of the limit towards higher energy with increasing absorber thickness has been found, amounting to 0.43 XU/mm and increasing linearly below 0.2 mm. The size and sign of the shift have given information of the spectrometer window curve. Extrapolation of the experimental results to zero absorber thickness yields the energy value 177.995 ± 0.030 XU or 69.509 ± 0.012 keV for W K.

P. E. BLOMBERG, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Determination of the effective neutron absorption cross section of reactor construction materials

Using the pile oscillator method, the effective neutron absorption cross sections of some materials (Al, Zr, Fe) have been measured. With this method, a sample is periodically moved from a position inside the reactor to another position, which may be entirely outside the reactor. The alternating component of the pile flux due to the oscillating sample is picked up by an ionization chamber system. The apparatus is designed to give the amplitude of the first harmonic of the modulation envelope. This measured value, corrected for some small effects, is proportional to the inserted absorption cross section. The effective absorption cross sections of the samples are related to standards of pure Al, for which the absorption cross section is known.

E. BLOMSJÖ, *Department of Physics, Atomic Energy Laboratory, Stockholm*

The temperature dependence of a U-D₂O-lattice measured in an exponential pile experiment

In our exponential pile assembly the moderator temperature has been varied by circulating the heavy water through a heated or cooled tube. Measurements have

¹ L. G. PARRATT, C. F. HEMPSTEAD and E. L. JOSSEM, *Phys. Rev.* 105, 1228 (1957).

been made in the temperature interval 10° – 80°C . The temperature coefficients for the diffusion length L in heavy water and the buckling B^2 of a hexagonal lattice (lattice pitch 20 cm) of 3 cm uranium rods in heavy water have been determined. The measured effects are quite small but because we make only relative measurements the uncertainty in dB^2/dT will nevertheless probably be smaller than 5 %. The measurement of dL/dT for D_2O has considerably smaller accuracy, principally due to the low intensity. The results obtained so far are only preliminary and the measurements will be continued later on.

J. BRAUN, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Gamma volume-sources in the reactor core

The calculation of gamma sources arising from different processes in the reactor core is reviewed. It is shown that the average total energy per fission is dependent on the type of reactor considered and for the UO_2 loaded D_2O moderated reactor considered in this paper may be estimated to 25.5 Mev/fission with a certain energy distribution. The connection between this figure and the volume-source is shown. The importance of the escape probability for the fuel element is pointed out. In the reactor mentioned above only 8.6 Mev/fission escapes from an element with a radius of 3.3 cm.

O. BRULIN and S. HJALMARS, *Department of Theoretical Physics, University of Stockholm*

A Dirac equation of spin 2 for the gravitational field

The present work is an investigation of the possibility of describing the gravitational field of empty space in the case of almost euclidean metrics by means of a Dirac equation. Such a Dirac equation is obtained as the irreducible spin 2 case, where the wave function components consist of the components of a 4-vector and of a symmetrical tensor of second rank, the latter being identified with the metric fundamental tensor. It is shown, that if the general mass term of the Dirac equation is specialized to zero mass in a suitable way, the resulting field equations are identical with Einsteins equations for the above-mentioned gravitational field. Hereby the 4-vector appears as a kind of potential to the metric tensor. The generalization of the Dirac equation to general relativity is under investigation.

O. BRYNGDAHL, *Department of Physics, Royal Institute of Technology, Stockholm*

Studies of diffusion in liquids by means of a shearing interferometer

Diffusion and other phenomena giving rise to a refractive index gradient in a solution can easily and rapidly be studied by a new interferometric derivative-registering method, utilizing birefringence interferences.

By choosing the conditions of the experiment and the method of registration in a suitable way, a great enhancement of the power of resolution results, which makes the method equally suited to measurements on medium and very low refractive index gradients. Advantages of the method are that only part of the Gaussian curve

(representing the ideal concentration gradient) near the inflexion points is used, and that an image of the whole diffusion column is obtained. In addition, the method is particularly valuable in the study of cases where the refractive index gradient has a low value. The possibility of arranging differential diffusion experiments with very low concentration differences also provides a convenient means of studying the concentration dependence of the diffusion coefficient.

J. O. BURGMAN, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Some problems in connection with an isotope separator ion source

A recent reconstruction of the oscillating electron type ion source used in the small electromagnetic isotope separator of the Werner Institute has in particular aimed at increased efficiency with solid charge material. This is achieved by making the discharge chamber gastight as far as possible and keeping it at a high running temperature by means of good thermal insulation and a directly heated anode, thus preventing unionized atoms escaping from the discharge. With suitable charge materials it is now possible to reach an overall efficiency of the separation process of about 10 %. In the preparation of radioactive samples for nuclear spectroscopy, which is at present the main field of application of the separator, sharp focusing is another factor of major importance. This imposes certain requirements on the mechanism of ion extraction and beam formation. Special attention is paid to the geometrical shape of the outlet plate of the ion source and the first electrode of the accelerating system. Satisfactory focusing for work in the heavy mass region is obtained with ion currents up to a few hundred μA .

G. BÄCKSTRÖM, *Department of Physics, University of Uppsala*

Some nuclei with possible vibrational excitation

In the double-focusing spectrometer group an extensive investigation of the decay of the neutron-deficient isotopes $\text{Au}^{192-196}$ is in progress. As the even-even nuclei in this region show constant level spacing, it has been suggested that this is to be attributed to surface phonons. Some experimental facts relevant to this interpretation are given. Further, evidence for a splitting of the degenerated second excited state in Se^{76} has been found, in accord with theoretical expectation.

I. CARLVIK and B. PERSHAGEN, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Development of methods for calculating lattice constants of heterogeneous thermal reactors

The existing methods for calculating lattice parameters have been examined in detail. During this work some new methods have been developed.

The determination of the thermal utilization f consists essentially of calculating the ratios between mean fluxes in different parts of a reactor core cell. The generally used diffusion theory does not give satisfactory results as the dimensions of the fuel bars are not large enough and the fuel is too strongly absorbing. We have combined

theory and experimental results to arrive at a simple method for calculating the flux ratios.

In the conventional method for calculating the fast fission factor ε one has to use cross sections that differ appreciably from directly measured cross sections. By using a two-group model with the boundary energy chosen at the threshold energy for fission in U^{238} it has been possible to use measured cross sections and also to apply homogenizing processes to complicated fuel elements.

The conventional method for calculating the resonance escape probability p assumes the source density of resonance neutrons to be constant in the moderator. In power reactors the distances between fuel elements are often so large that this assumption is no longer valid. We have proposed a theory that takes account of this variation in source density. This theory also distinguishes between different lattices, e.g. square and rhomboidal lattices.

The validity of the methods is tested by applying it to several exponential and critical experiments.

H. CONDÉ, *Research Institute of National Defence, Stockholm*

The generation and measurement of high thermal radiation intensities

The effects on various materials of very high thermal radiation intensities (> 75 cal/cm²) are studied. Various generators using carbon arcs and mirrors have been constructed. Intensities are measured absolutely with a water flow calorimeter.

A. DATNER, *Department of Electronics, Royal Institute of Technology, Stockholm*

On a plasma resonator

According to Herlofson a radio wave can be strongly reflected from an ionized column provided that:

$$1) \quad N_e = 2 \frac{m\varepsilon_0}{e^2} c\omega^2$$

where

N_e — electron density in the plasma

m — electronic mass

e — electronic charge

$\omega/2\pi$ = radiofrequency of the wave

$$\varepsilon_0 = \frac{10^{-9}}{36\pi} \text{ farad / meter}$$

2) the collision frequency of the electrons in the plasma is small compared to the frequency of the electro-magnetic wave.

3) the wave is polarized in such a way that the E -vector is perpendicular to the axis of the gas column.

In 1951 Romell was also able to verify this theory; in an experiment he obtained a very strong echo from a plasma column although the diameter of the column was only 1/10 of the wave length. The aim of the present investigation was to explore the properties of a plasma column as a wave guide component. A low pressure mercury

vapour discharge was chosen to give a plasma column with the properties mentioned above, and the tube was placed across the wave guide, perpendicular to its axis, in such a way that the third condition was fulfilled.

The preliminary results of such an experiment were presented in a paper given at the Swedish Radioscientific Conference 1954; they concerned work with wavelengths of 30 cm and 10 cm. More thoroughful measurements have later been made in a 6 cm wave-guide system.

In particular the impedance of such a component was measured, and also the attenuation introduced by the discharge tube as a function of a discharge current. Moreover, the resonance region was studied in detail. The resonance discharge current was both observed and calculated as a function of gas kinetic parameters, i.e. gas density, electron temperature etc. The time of ionization and of deionization was determined. Finally, noise measurements were made. The influence of the tube cross-section and of a magnetic field, transverse or longitudinal, upon the resonance effect was studied.

E. DJURLE and W. S. RODNEY, *Department of Physics, Royal Institute of Technology, Stockholm*

Instrumentation for phase contrast measurements in the near infra-red

An instrument for measuring refractive index in the infra-red is under construction. The instrument is based on the phase contrast principle and consists of an Ebert monochromator and a refractometer. The exit slit of the monochromator serves as the entrance slit of the refractometer. Mirror optics is used to facilitate focusing and to eliminate absorption problems.

The measurement of the contrast in the image will be made by optical energy compensation, with a Golay cell serving as a null detector.

The first measurements are to be made on air using wavelengths of the infra-red spectrum of Hg from about $1.0\ \mu$ to $2.3\ \mu$.

J. DUBOIS, *Department of Physics, Chalmers Institute of Technology, Gothenburg*

Determination of the half-lives of some mirror nuclides

The half-lives of the positron emitters C^{11} , N^{13} , F^{17} , Na^{21} , Al^{25} , P^{29} and Al^{26} , P^{30} have been determined.

The radioactive isotopes were produced by resonance capture of protons, accelerated by the Van de Graaff-generator at the Chalmers Institute of Technology. After activation the proton beam was switched off and the target turned to measuring position. A scintillation counter detected the positron radiation. The decay was measured using a 10-channel ring scaler, which recorded the counts during successive equal intervals. The length of the interval was mainly chosen according to Peierls method. Accurate corrections were applied to each measurement, one for the finite resolving time of the scalers and one for the background. The half-lives were calculated by the method of least squares from the logarithms of the corrected activities. A plot of the residuals shows the results to be very sensitive to impurity activities and other errors.

The deposition of radioactivity from nuclear weapons tests

For some years, investigations of the radioactive debris emanating from nuclear weapons tests are made in this country. The amount of ground deposition is determined from precipitation activity. The precipitation is collected in stainless steel funnels. The activity is concentrated in a paper-filter ion-exchanger device and determined by β -counting, γ -spectroscopy and to some extent radiochemical methods. From these measurements it is possible to evaluate the content of different isotopes, especially the long-lived ones. Investigations of the content of radioactive debris in the upper atmosphere are also undertaken by means of a filter unit, carried by a jet aircraft. These investigations have an interest from a geophysical point of view, as they make possible studies of the movements and exchange of matter of air-masses.

A. G. EKSPONG, *Department of Physics, University of Uppsala*

A new method for determining the direction of motion of particles giving tracks in nuclear emulsions

The direction of motion of charge particles traversing nuclear emulsions is usually determined by some measurements of the ionization in the beginning and at the end of the track segment available. This type of measurement is quite good in case the velocity of the particle changes enough within the available segment.

The new method consists in determining the direction of the δ -rays. The experimental tests show a preponderance of δ -rays emitted forward. This type of measurement can be applied also to track segments in which the particle velocity is essentially constant.

A. G. EKSPONG, S. JOHANSSON and B. E. RÖNNE, *Department of Physics, University of Uppsala*

Antiprotons in nuclear emulsions

A stack of nuclear emulsions was exposed to the negative particle beam of (700 MeV)/ c momentum from the Berkeley Bevatron in May 1956. The stack held 120 pellicles, 600 μ , of area $4'' \times 7''$. In this stack, which has been completely scanned once and is being rescanned, we have found 9 antiproton events. Some details have been observed about antiproton interactions.

T. ERICSON, *Department of Theoretical Physics, University of Lund*

On the level density of deformed nuclei

The success of the unified model in describing the low energy spectra of deformed nuclei has raised the question to what extent these ideas can be applied to regions of higher excitation. From a simplified unified model the nuclear level density is calculated by statistical methods up to an excitation of about 10 MeV for heavy deformed nuclei. The nucleon interaction is introduced in terms of a pairing energy.

With increasing excitation more and more pairs are broken. The distribution of spin and parity among the levels is determined by the different possible couplings of the unpaired nucleons and by the collective modes of excitation.

K. B. ERIKSSON, *Department of Physics, University of Lund*

New observations in the spectrum of the singly-ionized nitrogen atom

The spectrum of ionized nitrogen has been studied in the region 10 547–2077 Å by using large concave-grating spectrographs and a spark-generated high-frequency electrodeless discharge. About 450 spectrum lines, experimentally classified as N II, have been measured.

Analysis of the new data has given 52 new levels and approximately 200 newly-classified spectrum lines. The quintet terms have been connected with the main term system by the observation of the resonance lines. The ionization limit has been determined from selected $2s^2 2p\ nf$ series with the result $2s^2 2p\ ^2P_{1/2} = 238\,750.5\text{ cm}^{-1}$, which is 78 cm^{-1} higher than the previously accepted value.

G. ERLANDSSON, *Department of Physics, University of Stockholm*

First rotational transition of ND_3

The $J = 0 - 1$ rotational transition of N^{14}D_3 has been measured at about 0.97 mm wavelength. The line is split by inversion in two components at 306 735.0 MHz and 309 909.4 MHz respectively. The difference 3174.4 MHz represents the sum of the inversion splittings of the levels $J = 0$ and $J = 1$. The observed intensities are in substantial agreement with the theoretical ratio 1:10 of the statistical weights. The stronger component was also resolved in a hyperfine structure due to the N^{14} quadrupole coupling. The coupling constant was estimated to $-4.20 \pm 0.15\text{ MHz}$. The rotational constant has been calculated to be $B_0 = 154\,162.7\text{ MHz}$, equivalent to 5.14218 cm^{-1} , using $D_J = 3.4\text{ MHz}$ from infrared work. The corresponding value from the infrared rotational spectrum is 5.13 cm^{-1} . The agreement is thus satisfactory.

This work was done at Duke University, USA, in collaboration with professor Walter Gordy.

S. FLODMARK, *Department of Theoretical Physics, University of Stockholm*

On the electron distribution in crystals of metal borides of MeB_6 type

The MeB_6 structure has earlier been investigated by Longuet-Higgins *et al.*¹ and by the present author.² The main purpose of the present investigation is to find an estimation of the extent of valence electron orbitals of boron with the principal quantum number $n = 3$. The symmetry of these orbitals is closely connected with the crystal framework.

Bloch wave functions have been constructed from site orbitals, which are linear combinations of atomic orbitals. Variation of the energy leads to a large number of

¹ H. C. LONGUET-HIGGINS and M. DE V. ROBERTS, Proc. Roy. Soc. A 224, 336 (1954).

² S. FLODMARK, Arkiv för fysik 9, 357 (1955).

secular equations of rather high degrees. It is planned to solve these equations numerically by use of the electronic computer BESK. This will give the energy bands as well as the electron distribution. The necessary one-electron integrals have earlier been computed¹ with the aid of BESK.

B. FORKMAN and S. A. E. JOHANSSON, *Department of Physics, University of Lund*

Photodisintegration of oxygen

Oxygen has been bombarded with bremsstrahlung at various energies. The emitted protons were recorded by nuclear emulsions. The resulting proton spectra exhibit well resolved peaks, corresponding to resonances in the photon absorption process. If the maximum bremsstrahlung energy is set fairly close to the threshold, only a limited number of levels are excited, and the proton groups are well resolved. When the maximum energy is increased, the proton spectra become more complex, but knowing the lower resonances one can calculate the contribution from the lower resonances and subtract this. In this way it is possible to resolve the proton spectra step by step, by using different bombarding energies. The width of the peaks gives some information about the character of the photon absorption. For the strongest peaks one can plot angular distributions which give additional information about the resonances.

S. VON FRIESEN, *Department of Physics, University of Lund*

The elementary particles 1957

A brief survey is presented of the actual state of our knowledge of the elementary particles and of their transformations.

T. R. GERHOLM, *Department of Physics, University of Uppsala*

Some effects of configurational mixing in odd *A* nuclei

Magnetic dipole transitions between nuclear states differing by two units in angular momentum should be strictly forbidden according to the single particle model (*l*-forbiddenness). Nevertheless many *l*-forbidden M1 transitions have been found to occur, but the transition rate appears to be retarded by factors of about 200 to 400, compared to corresponding allowed transitions. The occurrence of *l*-forbidden M1 transitions can be understood, if anomalous magnetic moments are introduced due to exchange currents and/or velocity dependent nuclear forces, such as the spin-orbit force. Alternatively, one can explain these *l*-forbidden M1 transitions as an effect of configurational mixing. If the latter point of view is accepted these M1 transitions provide sensitive tests of the purity of the single particle wave functions, since the matrix elements—and thus also the transition rates—should be proportional to the amplitudes of the admixed configurations.

In experiments in progress at this institute, *l*-forbidden M1 transitions are studied in three different ways: 1) from measurements of lifetimes of excited nuclear levels the matrix elements are obtained.

¹ S. FLODMARK, *Arkiv för fysik* 11, 417 (1957).

2) precise measurements of internal conversion coefficients also give information about the matrix elements.

3) angular correlation experiments with cascading l -allowed and l -forbidden M1-transitions give the ratio of the corresponding two matrix elements.

Some results already obtained are presented. It is concluded that these M1 transition can be explained by small amounts of admixtures of excited single particle shell model configurations, as recently shown by Arima, Horie and Sano (private communication).

G. GRAN, *Department of Physics, Royal Institute of Technology, Stockholm*

Coordinate meter with optical-photometrical setting control

This device is for determining the fiducial position of the lines on a spectrum plate or a plate with any other sort of indices. An image of the line is projected on a thin slit. This image is made to move across the slit 100 times per second, by interposing a rotating octagonal prism in front of the fixed slit. Scanning in two directions is done by using reversion prisms. Behind the slit is mounted a photo-multiplier cell, the output of which is fed directly to the vertical input of an oscilloscope. A 50 Hz signal is fed to the horizontal input. At opposite sides of the screen two traces appear which can be made to coincide. If the line is asymmetrical, one can make the settings at any chosen point of interest, for example the half intensity point.

L. HEDIN and L. HULTHÉN, *Department of Theoretical Physics, Royal Institute of Technology, Stockholm*

Phenomenological deuteron wave functions

The ground state of the deuteron is a ${}^3S_1 + {}^3D_1$, which gives the following expression for the wave function:

$$\psi = \frac{u(r)}{r} Y_{1,0,1}^M + \frac{w(r)}{r} Y_{1,2,1}^M$$

u and w satisfy certain differential equations, which contain the unknown nuclear potentials. The $Y_{j,l,s}^M$ are known functions.

Hulthén and Sugawara have suggested analytical expressions for u and w which have the right asymptotic behavior for large r and tend to zero with r . ("The Two-Nucleon Problem," Handbuch der Physik XXXIX; to be published). Experimental values from low energies fix some constants in these expressions for u and w .

With u and w thus "known" we can derive the corresponding potentials from the above mentioned differential equations.

The numerical work was done by H. Condé and L. Hedin (1955), B. Sjöberg (1956) and N. Johansson (1957).

S. HELLSTRÖM, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Some experiments with scintillating gels

In our search for suitable methods which will permit absolute determinations of active isotopes we have started to examine the possibility of using scintillating gels.

The first series of measurements are being made to determine the efficiency that can be obtained when measuring a weak β -emitter in a scintillating gel. Co^{60} -samples are used.

L. O. HENDEBERG, *Department of Physics, Royal Institute of Technology, Stockholm*

Response functions (contrast transfer functions) of photographic emulsions

Exposing an emulsion film to an image pattern with a sinusoidal variation of intensity in space, along the film, is a new method for studying the light diffusion which limits the resolution in that emulsion film. This method leads to ct-curves (contrast transfer curves), where the abscissa represents the spatial frequency (in lines/mm) and the ordinate the contrast of the image in the emulsion. These ct-functions are dependent on the thickness, the granularity and other details of the emulsion. The ct-functions of an emulsion are shown to vary with wavelength of the light; here tested for bands at $456\text{ m}\mu$, $546\text{ m}\mu$, and $679\text{ m}\mu$. The effect of diffusion here considered should be well distinguished from a phenomenon of a different nature, the Eberhard effect.

G. HETTINGER, K. LIDÉN and N. STARFELT, *Department of Physics, University of Lund*

Bremsstrahlung spectra from X-ray tubes

A NaI(Tl) scintillation spectrometer was used to study spectra of unfiltered and filtered bremsstrahlung from commercial X-ray tubes, operating at constant potentials between 45 kV and 250 kV. The measured pulse height distributions were corrected with the aid of an automatic computer (SMIL, Lund). The intensity of K X-radiation at different tube voltages was studied. Spectra obtained with different filters were compared with spectra calculated from the corresponding measurements of the unfiltered radiation. A method was developed for deriving the shape of X-ray spectra produced by X-ray tubes operating at potentials of various wave forms.

INGA HJALMARS, *Department of Theoretical Physics, University of Stockholm*

The negative hydrogen molecule-ion

The only previously published investigation¹ of the stability of the negative hydrogen molecule-ion H_2^- was carried out by the valence bond method, using two variable parameters, the internuclear distance R and the effective charge Z of the $1s$ atomic orbital. It was found that H_2^- should be stable in comparison to $\text{H} + \text{H}^-$, computed in the same approximation (in which H^- is unstable), but unstable in comparison both to $\text{H}_2 + e$ and to $\text{H} + \text{H} + e$.

The present investigation includes computations by the molecular orbital method using two variable parameters, R and Z , and by the valence bond method using three, four or five variable parameters, R , Z , Z' , Z'' and a parameter making allowance for the polarization of the atomic orbitals.

¹ H. EYRING, J. O. HIRSCHFELDER and H. S. TAYLOR, *J. Chem. Phys.* 4, 479 (1936).

S. HJALMARS and O. BRULIN, *Department of Theoretical Physics, Royal Institute of Technology, Stockholm*

Dirac equations for spin 2 particles with unique mass

It is well-known, that particles of arbitrary spin can be described by Lorentz invariant Dirac equations. If such an equation is supposed to represent a particle of unique mass, it seems necessary that all components of the wave function satisfy Klein-Gordon equations with the same mass constant. However, it is impossible to fulfil this condition with Hermitian matrices for any spin higher than 1, if the mass term in the Dirac equation is specialized to a constant times the unit matrix. The present work is an investigation of the probably most interesting irreducible spin 2 case, where the components of the Dirac wave function consist of the components of a symmetric tensor of the second rank and of a 4-vector. The most general mass term of the Dirac equation is considered, and it is proved that with a suitable specialization of this term the above-mentioned condition for unique mass can be satisfied.

P. HJELMSTRÖM, *Department of Physics, Royal Institute of Technology, Stockholm*

The influence of some typical aberrations on the contrast transfer functions

The correlation between large aberrations and contrast transfer functions (response functions) has been treated previously, both theoretically and experimentally.^{1, 2, 3, 4} In this paper the main difficulties are stated, and a description is given of experiments now being conducted at the Institute of Optical Research. Here a simple achromatic system is tested by means of an integrator, tracing response curves. The limitations of this approach are pointed out. Results are presented in graphical form.

L. HULDT and A. LAGERQVIST, *Department of Physics, University of Stockholm*

Spectra of metal oxides in the near infra-red

Spectra from an acetylene-air flame fed with salts of different metals have been recorded, using a commercial spectrophotometer with rock salt prism (Perkin-Elmer mod. 13). In addition to bands of metal oxides in the visible and near infra-red region, which were formerly known, the following emission spectra were observed: Fe up to 3.6μ ; Co $0.85\text{--}2.5 \mu$; Mn $0.8\text{--}2.5 \mu$; V up to 3.6μ . No emission from the alkaline earth metals appeared above 1μ . The fundamental vibration bands of the oxides were too weak to be observed. In view of the low resolution and the complication caused by overlapping bands of H_2O and CO_2 , no studies of the structure of the recorded spectra have hitherto been made. Details of the investigation will be published in *Arkiv för fysik*.

¹ H. H. HOPKINS, *Proc. Roy. Soc., A* 231, 91 (1955).

² M. DE, *Proc. Roy. Soc., A* 233, 91 (1955).

³ E. L. O'NEILL, *Selected Topics in Optics and Communication Theory*, Boston 1956.

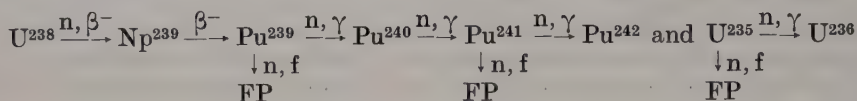
⁴ G. BLACK and E. H. LINFOOT, *Proc. Roy. Soc., A* 239, 522 (1957).

The new Physics Institute of the University of Stockholm

This lecture gives a brief account regarding a planned new building for Physics at the University of Stockholm to be ready for use in 1959/1960.

Long-time variations in a thermal reactor with natural uranium

Relevant reactions are the following, where f indicates fission and FP represents "Fission Products":



An example of a time equation is given. The ratio (moderator volume)/(uranium volume) is important because the neutron spectrum is influenced by it. The production of Pu gives fissionable atoms which contribute to the energy production and neutron economy in the reactor.

Resolution and interferometric accuracy

The problems of three-dimensional imaging with limited optical communication channels are complicated if the details considered have dimensions of the same order as the wavelength. The treatment of lateral resolution of amplitude objects is well known. For interferometric accuracy when measuring extended and homogeneous objects no limits exist other than photometric threshold sensitivities, and $\lambda/10000$ is easily obtained, say, in polarimeters. When both qualities are required at the same time, information considerations show that interrelations exist.^{1, 2}

In this paper it is shown how resolution and interferometric accuracy must be balanced in interference microscopes. For those in current use by biologists, corrections of up to 15 % are shown to be necessary in the depth values due to high apertures, and corresponding uncertainties are then to be reckoned with for unknown objects. The use of low apertures increases the accuracy of depth measurements but reduces resolution.

Polarization in elastic and inelastic scattering of protons from light nuclei

In all previous double-scattering experiments the asymmetry in the scattering of polarized particles has been studied. In this experiment the polarization, which

¹ E. INGELSTAM, *Arkiv för fysik* 7, 309 (1953).

² E. INGELSTAM, *Problems in Contemporary Optics*, p. 128, Firenze 1956.

in general is not immediately given by the asymmetry, has been measured for 173 MeV protons, scattered elastically and inelastically by carbon, oxygen, and calcium. This was done by using a high-resolution 90° magnetic analyzer between the first and the second scatterer. The first scattering angle was varied, whereas the second scattering angle was fixed, this part of the apparatus being used merely as an *analyzer* of the polarisation.

The polarizations of scattered protons corresponding to low-lying levels of all three elements are large and show strikingly similar angular patterns. The higher levels are much less polarized. The elastic polarizations differ from the elastic asymmetries only in having deeper diffraction minima.

B. JOHANSSON, *Nobel Institute of Physics, Stockholm*

Coincidence arrangement of high time resolution, used with a 100-channel pulse-height analyzer

For studying the decay schemes¹ of Bi^{203} and Bi^{204} a gamma-electron coincidence arrangement with a resolving time (2τ) of $0.03 \mu\text{s}$ was utilized. For this purpose an intermediate image β -spectrometer with an anthracene crystal for the electron detection and a NaI crystal for the γ -detection was used. The coincidences were collected by a 100-channel pulse height analyzer. To increase the energy resolution of the γ -detector the crystal was mounted directly on the multiplier. The multiplier system was then placed inside the polepiece. To reduce the influence of the magnetic field a compensating coil was wound around the cover of the multiplier. This arrangement gave nearly the same energy resolution inside and outside the spectrometer—9.2% for the 661 keV γ -ray in Cs^{137} . The coincidence unit used has a gated fast pulse generator in each channel. The pulse generator is triggered by the detector pulse only if a gate pulse, selected by a differential discriminator, arrives at the same time. Because the rise time (about $0.25 \mu\text{s}$) of the detector pulses is independent of the pulse size, a big pulse will trigger the pulse generator earlier than a small one for a certain triggering level. To compensate for this effect a correcting circuit has been designed, which reduces the resolving time to a value limited only by the time spread in the NaI crystal.

This arrangement made it possible to use a resolving time of $0.03 \mu\text{s}$ when the coincidences were collected by the 100-channel pulse height analyzer. The coincidence efficiency was constant over the whole range of the analyzer.

E. JOHANSSON, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Measurement of fast neutron flux by means of threshold reactions

A method of detecting fast neutrons is to use threshold activation. The activation is then due to neutrons with an energy above a certain value. In the present case use has been made of the reactions $\text{Al}^{27}(\text{n}, \alpha)\text{Na}^{24}$ and $\text{P}^{31}(\text{n}, \text{p})\text{Si}^{31}$, which have the thresholds 3.3 MeV and 0.7 MeV respectively. The Na- and Si-activities produced have been measured absolutely, and the fast neutron flux has then been obtained using published values of the reaction cross sections. The largest uncertainty arises from the fact that these cross section values are not known with good accuracy.

¹ R. STOCKENDAL *et al.*, see below.

Precision measurements of atomic spectra in the wavelength region 1–3 μ

A plane grating scanning spectrometer with lead-sulfide photocell has been built in this laboratory for use in the wavelength region 1–3 μ . The wavelengths are determined by means of an interferometrically established scale. White light from a concentrated arc lamp is allowed to pass through the spectrograph and also through a Fabry-Perot interferometer. This produces a spectrum with a series of Edser-Butler fringes, which are equally spaced in wave number (for the radiation in the air of the interferometer). The wave-number scale thus obtained is calibrated by means of standard lines in different orders. The fringes and the spectrum under investigation are then registered simultaneously on the same record. So far measurements have been made in the spectra of Li, Na and K. Observations of accurately known rare-gas lines as well as the application of the combination principle indicate an error latitude of $\pm 0.02 \text{ \AA}$ at 2 μ .

Interferometric measurements of the thickness of transparent and opaque thin films

By proper use of the interferometric method it is possible to measure the thickness of transparent and opaque objects with high precision. With a new type of interference microscope, using birefringent plates in the eye-piece, thicknesses can be measured with an error of magnitude of 20 $\text{\AA}$. This microscope is presently built only for use in transmission, but the principle can also be applied for reflection measurements.^{1, 2}

If the films to be measured are reflecting or can be coated with a reflecting layer, the multiple beam interference technique can reduce the error magnitude to 5 or 10 $\text{\AA}$.^{3, 4} To obtain this precision the films must rest on surfaces which are plane to the same extent. Examples are given of measurements of some phase-objects etched in glass and of aluminium films used as catching foils in α -ray experiments.

The production of isotopes by the cosmic radiation

It is well known that the cosmic radiation produces a number of radioactive isotopes in the atmosphere. Stable isotopes are of course also produced. If the production rate is high enough it might slightly change the isotopic composition of some elements. The production rate has been calculated with the present cosmic ray intensity. It appears that this effect might produce a measurable change in the case of a few elements. If the cosmic ray intensity has been greater in the past a considerable change can be expected. A study of the variations in isotopic abundance might then give an estimate of the integrated cosmic ray flux or at least an upper limit for it.

¹ L. P. JOHANSSON and B. M. A. AFZELIUS, *Nature* 178, 137 (1956).

² L. P. JOHANSSON, *Exp. Cell Research* (in press).

³ S. TOLANSKY, *Multiple Beam Interferometry*, Oxford 1948.

⁴ Pamphlet from AB C. E. Johansson.

S. A. E. JOHANSSON, *Department of Physics, University of Lund*

On the width of the giant resonance in photonuclear reactions

The shape of the giant resonance in photonuclear reactions is discussed in terms of various models. The available experimental material is reviewed. It is shown in what cases the measured cross-section curves give the shape of the total cross-section curve for photon absorption. It turns out that there exists a good correlation between the width of the giant resonance and the shape of the nucleus. Deformed nuclei have a considerably broader resonance than nondeformed. This supports the collective model for the photonuclear reactions.

B. JUNG, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

The decay of $\text{Pb}^{199\text{m}}$, $\text{Pb}^{197\text{m}}$ and $\text{Pb}^{195\text{m}}$

A low lying, high spin state ($i\ 13/2$ in single particle notation) has been observed in Pb^{199} , Pb^{197} , and Pb^{195} . The decay schemes show a regular trend. In Pb^{199} an M4 internal transition to an $f\ 5/2$ state has been observed, in Pb^{197} a corresponding M4 transition competes with an electron capture branch to an $h\ 11/2$ state in Tl (E.C./I.T. = 4.2 ± 0.3) and in Pb^{195} only electron capture decay to an $h\ 11/2$ state in Tl has been observed. The $h\ 11/2$ states in Tl^{197} and Tl^{195} are de-excited by E3 transitions to $d\ 5/2$ states and have half-lives measured as 0.55 ± 0.10 s and 3.5 ± 0.4 s, respectively. Level schemes involving also transitions from the $d\ 5/2$ states to the $s\ 1/2$ ground states have been constructed.

The measurements on conversion electrons were made in an iron-yoke and an iron-free double-focusing β -spectrometer and an $e^- - e^-$ coincidence spectrometer. A scintillation spectrometer connected to a convertible pulse height and time analyser was used to measure the half-lives of the $h\ 11/2$ states in Tl. For the separation of Tl formed in decay of Pb rapid chemical procedures were worked out, making use either of extraction with ether or separation in an ion exchange column.

This paper includes work done by G. Andersson, E. Arbman, J. O. Burgman, B. Jung, I. B. Svensson, and P. A. Tove.

E. KARLSSON, T. R. GERHOLM and T. LINDQVIST, *Department of Physics, University of Uppsala*

Applications of the multichannel goniometer (MCG)

The MCG is an apparatus for angular correlation measurements.¹ Four scintillation detectors, placed asymmetrically, view the same source. All six coincidence combinations between these are recorded simultaneously. A "coincidence cross delay" speeds up the measurements by another factor of two. The instrument is self-monitoring, and the coincidence counting rate is an order of magnitude higher than in a conventional arrangement with two detectors.

The MCG is specially suitable for measurements on very short-lived isotopes. It has been used for studying the admixture of l -forbidden M1 transitions in mass-separated odd Tl isotopes. From the mixing ratios thus obtained the corresponding M1 matrix elements are calculated on the basis of shell-model assumptions.

¹ T. R. GERHOLM, T. LINDQVIST and H. DE WAARD, *Nuclear Instruments*, 1, 107 (1957).

An electron spin resonance study of γ -irradiated dextran

Dextran treated with γ -rays from Co^{60} at a dose rate of 10^4 rep/min and a pressure of 0.01–0.02 mm Hg degrades. The breaking up of the chemical bonds gives rise to unpaired electron spins, which can be studied by means of electron spin resonance technique. Samples of dextran irradiated to a dose of 1.5, 4.0 and 6.5 Mrep show a concentration of spins proportional to the dose. The resonance spectrum consists of one main line corresponding to a g -value of 2.005. The line width is 26 ± 1 gauss. There is a not very well resolved hyperfine structure, which becomes less pronounced at higher doses. The decrease in the number of spins with time after irradiation was studied at 20°C and 50°C. The preliminary data indicate two different decay processes at 50°C. Assuming the decay to be exponential, half-lives of 8.5 hours and 12.5 days were obtained. At 20°C the number of radicals decreased very slowly, corresponding to an approximate half-life of 12.5 weeks. From these data the activation energy is estimated to be 10–30 kcal/mol. Some experiments carried out in air showed a more rapid decay.

O. KLEIN, *Department of Theoretical Physics, University of Stockholm*

Some remarks on the inversion theorems of quantum field theory

In connection with the new parity situation, revealed by the experiments on weak interactions suggested by Lee and Yang, the five coordinate inversions of five-dimensional relativity theory, each corresponding to a change of sign of one of a set of five anticommuting eight-row matrices $\gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4$ (extended Dirac matrices), are studied. Using this theory as an auxiliary model to a physical theory, an eight-component spinor is formed by the combination of a four-component Dirac spinor φ with its conjugate complex φ^* . As is then shown, the theory is no longer invariant under the old-type space inversion—which would entail a change of sign of γ_0 —but only under the new inversion introduced by Lee and Yang and Landon, according to which an antiparticle is the mirror image of a particle.

B. KLEMAN, *Department of Physics, University of Stockholm*

The blue-green bands in the spectra of N-type stars

The strong blue-green bands which appear in the spectra of certain stars have been excited in the laboratory (Astroph. J. 123, 162, 1955). Arguments are given in support of the suggestion made in this paper that the unidentified bands are due to an Si–C–C molecule.

K. KRISTIANSSON, *Department of Physics, University of Lund*

Energy loss in K^+ -meson scattering in nuclear emulsions

The energy loss in the scattering of K^+ -mesons by nuclei in nuclear emulsions has been studied in the energy region 75–130 MeV. About 50 scattering events with an

angle exceeding 12° have been investigated. The energy of a K-particle before and after the collision has been determined by grain counting. Most scatterings are elastic or nearly elastic. Only about 25 % of the scattered particles show an energy loss larger than 15 %. Events where the energy loss exceeds 50 % are very rare.

H. S. KÖHLER, *Department of Theoretical Physics, University of Uppsala*

Calculations on the polarisation of nucleons scattered elastically by nuclei

An optical model nucleon-nucleus interaction of the form¹

$$V = V(r) (1 + i\beta) + \alpha(1 - i\gamma) \frac{V'(r)}{r} \mathbf{l} \cdot \mathbf{s} \quad (1)$$

has been assumed. In a certain approximation that mainly requires that α is small one will obtain for the polarisation of high energy neutrons²

$$P(\theta) = \frac{\alpha(\gamma + \beta) k^2 \sin \theta}{1 + \beta^2 + \frac{1}{4} \alpha^2 k^4 1 + \gamma^2} \sin^2 \theta \quad (2)$$

where θ is scattering angle and k wave number. The same result is obtained in the Born approximation which however requires the total V to be small. The coulomb-field, effective for protons, and the electromagnetic spin-orbit coupling³ will modify the result (2) for small angles and also for angles around the diffraction minima, where the exact calculations will involve deviations from (2) too.

If in (1) it is assumed that $\gamma = 0$ and $\alpha = -30 \cdot \frac{\hbar^2}{2M^2 c^2}$ there is for heavy nuclei (e.g. Ag) good agreement with experiments for all angles less than about 30° , but for light nuclei (e.g. C) only^{2,3} for small angles ($< 10^\circ$). For the larger angles there is agreement in the case of light nuclei, if $\gamma \approx 1$. Although the measurements on heavy nuclei are also compatible with a $\gamma > 0$, agreement will probably be less for these than for the large angle scattering of light nuclei.

A. LAGERQVIST, *Department of Physics, University of Stockholm*

Die Dissoziationsenergie des Stickstoffoxydes

Durch bandenspektroskopische Rotationsanalysen des Absorptionsspektrums von NO zwischen 1600 Å und 2000 Å ist es gelungen, einen Wert der Dissoziationsenergie dieses Moleküles zu bestimmen. Der Wert ist 6,50 eV. Hieraus folgt, dass die Dissoziationsenergie von N₂ 9,76 eV ist.

¹ See e.g. A. SJÖLANDER and S. KÖHLER, Arkiv för fysik 8, 521 (1954). E. FERMI, Nuovo Cimento 11, 407 (1954).

² S. KÖHLER, Nuovo Cimento 2, 911 (1955); S. KÖHLER, Nuclear Physics 1, 433 (1956).

³ T. ERIKSSON, Nuclear Physics 2, 91 (1956/57).

Friction damping of an oscillating system

It is customary to write the equation of motion for an oscillating system with a dissipative term corresponding to viscous damping only. In many cases, however, it is to be expected that damping due to friction actually plays an important part. In the course of an investigation of ground tremors produced by blasts from detonating charges, the behaviour of the recording instrument has been analysed with a particular view to the conditions of damping. It turns out that the viscous term can be neglected entirely in this case. The situation as regards damping is then governed by a frictional force of constant magnitude, but directed in such a way as to always oppose the relative motion; for the normal modes of vibration this results in amplitudes which decrease linearly, not exponentially, with time.

Radiological use of the proton beam of the Uppsala synchrocyclotron

The application of the external proton beam for irradiation experiments is described. The required parallelity and homogeneity are brought about by the use of focusing magnets and sweeping coils. Dosimetry is performed with the aid of ion chambers, photographic films and carbon activation.

The radiophysical properties of the protons are now studied in special experiments. The average range in lucite is equivalent to 22.7 g/cm². The corresponding proton energy is 185 MeV. Scattering and range straggling are both inconsiderable. The average rate of energy loss in matter increases as the particles loose energy, and reaches a peak just before they stop.

These properties make the beam a valuable tool for different radiological experiments, as a review of the current work will exemplify.

Slow neutron spectrum measurements with the Swedish heavy water reactor, R 1

During the last few months a slow chopper with associated time-of-flight equipment has been put into operation at the Swedish reactor, R 1. At first the effort has been concentrated on a measurement of the slow neutron spectrum shape in the wavelength region from 0.8 Å to 11 Å. It is shown that the spectrum of neutrons emerging from an experimental hole is very nearly Maxwellian in shape, corresponding to a neutron temperature of 360°K, i.e. 50° above the moderator temperature. In the region of cold neutrons, $\lambda > 4$ Å, the spectrum falls off according to the law $I \sim \lambda^{-4.5}$. In subsidiary measurements it is shown that the proportion of neutrons below the Be cut off at 4 Å is 4.5 % of the complete Maxwellian distribution. These are the neutrons that can be used in "cold neutrons research". The flux of those cold neutrons is shown to be $2 \cdot 10^6$ n/cm²s at a reactor power of 300 kW. This figure compares favourably with the flux from much larger graphite reactors.

B. LAURENT, *Department of Theoretical Physics, University of Stockholm*

An attempt to construct a quantum gravidynamics

An attempt is made to construct a quantum gravidynamics with use of the Feynman-quantization. The guess is made and motivated that, for the purely gravitational case, the measure in the functional integral ought to be merely the product of the $d g_{\mu\nu}(x)$. The general covariance of the theory is discussed.

P. LINDBERG, *Research Institute of National Defence, Stockholm*

The performance of optical radiation detectors from the point of view of information

R. C. Jones¹ has introduced a concept for describing the sensitivity of optical radiation detectors in terms of signal-to-noise ratio. According to him the detectivity D of a detector is defined as the reciprocal of the radiation power giving a signal equal to the internal noise of the detector. If the chopping frequency of the radiation and the band width of the detector are given suitable values, the detectivity is

$$D = k_n A^{-1/2} \tau^{n/2}$$

where A is the sensitive area of the detector and τ is the time constant. n is a class number of the detector.

By applying information theory it is shown that the maximum information capacity of an optical signal is independent of τ but depends on the radiation power and the constant k_n of the detector.

Certain results are reported about the information rate obtainable in optical scanning.

J. O. LINDE, *Department of Physics, Royal Institute of Technology, Stockholm*

Electrical resistance of metallic solid solutions at low temperatures

In the physics laboratories of the Royal Institute of Technology a Collins helium cryostat has now been installed, with a recovery system for the helium gas attached to the apparatus.

The first measurements performed with the cryostat concern electrical resistivity properties of some alloys with copper, silver or gold as basic metal. A fairly large number of alloys containing transition metals or other elements as solutes has been investigated in the temperature range 1.2–4.2°K, in some cases also to higher temperatures (about 20°K). The characteristic minima and maxima of the resistance, in its dependence on temperature in the low-temperature range, have been studied.

It seems possible to correlate the observed electrical effects with the magnetic properties of the metals (exchange effects between the magnetic dipoles).

¹ R. C. JONES, "Performance of detectors for visible and infrared radiation", *Advances in electronics* 5, 1 (1953).

I. LINDGREN, *Department of Physics, University of Uppsala*

Atomic beam apparatus for measurements of spins and magnetic moments of radioactive nuclei

An atomic beam resonance apparatus with six-pole focusing magnets has been constructed at the Physics Department of the University of Uppsala. This apparatus will be used for measurements of spins and magnetic moments of radioactive nuclei. The focusing magnets give this type of apparatus a higher luminosity than the conventional type, and therefore it is very suitable for work with radioactive isotopes.

The apparatus has been adjusted using a beam of ordinary potassium. Potassium is detected with a surface ionization detector and the ion current is measured with a sensitive direct current amplifier. The resonance spectrum at very low external magnetic fields, i.e. $\Delta F = \pm 1$ transitions, has been studied. The measured hyperfine structure separation is

$$\Delta\nu(\text{K}^{39}) = 461.720 \text{ MHz}$$

which is in good agreement with previous measurements. In the work with radioactive isotopes, potassium will be used for accurate measurements of the constant magnetic field, where the transitions take place (the C-field).

The radioactive isotopes will be detected by their own activity. The beam is collected on a plate, which can easily be removed from the vacuum chamber, and the activity is measured with a low background scintillation counter. At the resonance frequency the over-all activity is maximum.

From the resonance frequency at different external fields, the nuclear spin and hyperfine structure interaction constant can be calculated. By comparison with other isotopes of the same element, the magnetic moment can then be determined using the Fermi-Segré formula.

Our first task with this apparatus is to determine the nuclear spin and magnetic moment of Bi^{206} . It is of particular interest to find the spin of Bi^{206} in the ground state, for the spins of the excited states have so far been measured only in relation to the ground state.

T. LINDQVIST and I. MARKLUND, *Department of Physics, University of Uppsala*

Mixing ratios of $2^+ \rightarrow 2^+$ transitions in some even-even nuclei

Mixing ratios of $2^+ \rightarrow 2^+$ transitions in Se^{76} , Te^{122} , Te^{124} and Os^{186} have been measured by means of directional gamma-gamma correlations. Ten other similar cases in even-even nuclei are known from earlier work. The E 2 radiation is dominating, although the amount of M 1 radiation is measurable. The investigated transitions are examples of transitions between vibrational states, which according to the theory should proceed by pure E 2. The presence of M 1 might indicate that the wave functions involved are not pure. The possibility of emission of E 0 conversion electrons has been discussed. In six cases an upper limit could be assigned to the emission rate.

J. LINDSKOG and T. G. GERHOLM, *Department of Physics, University of Uppsala*

Coincidence spectrometer for millimicrosecond lifetime measurements

The electron-electron coincidence spectrometer developed at this institute has been reconstructed in order to make it possible to measure millimicrosecond lifetimes

of specified nuclear energy levels. The ultimate limitations encountered in this fast coincidence technique are briefly reviewed, and it is shown that the coincidence spectrometer method implies several advantages. With the present technique, life-times down to 5×10^{-11} s can be measured. Improved photomultipliers, now under development at the RCA laboratories, will lower this limit.

K. LJUNGGREN, INGRID FOGELSTRÖM-FINEMAN, L.-G. ERWALL, T. WESTERMARK and B. SJÖSTRAND, *Department of Physical Chemistry, Royal Institute of Technology, Stockholm*

Gamma-spectrometric activation analysis by means of the Swedish reactor R 1

Activation analysis by means of neutron induced radioactivity is usually based upon chemical separation of the different elements present in the sample. In many cases this separation can be avoided, if the energy distribution of the emitted gamma radiations is studied. This can be achieved by scintillation spectrometry. An automatically scanning, single-channel scintillation spectrometer with a $3'' \times 3''$ sodium iodide crystal has been used for analysis of samples of various materials, irradiated in the R1 reactor of AB Atomenergi in Stockholm, in fluxes of about 5×10^{11} n/cm² s.

The apparatus is described, and several examples of performed analyses are given

A. LODDING, *Department of Physics, Chalmers Institute of Technology, Gothenburg*

Recent studies of the Haeffner-effect

The isotope effect due to the passage of direct current through molten metal was recently investigated in several elements. The mass effects, $\mu = (\Delta v/v)/(\Delta M/M)$, are of the order of magnitude 10^{-5} . The markedly positive temperature characteristic of μ discovered in indium and gallium seems to be absent in cadmium.

The Haeffner-effect can be pictured as arising from self-transference in molten metals, which means that disordered ions, concentration c_b , migrate with a velocity v_b through the crystalline lattice of ordered ions. Under the assumption that the self-transference is induced solely by electron friction against disordered ions, the following expression can be derived for the self-transference number $U^+ = c_b v_b/v$, where v = ion velocity relative to the electron cloud:

$$U^+ = \frac{N_0 e^2}{k} \cdot \frac{\varrho \cdot \gamma \cdot D}{M T} Z^2.$$

In this expression the following notation is used:

N_0 = Avogadro's number	D = self-diffusion coefficient
e = electronic charge	M = atomic weight
k = Boltzmann's constant	T = absolute temperature
ϱ = resistivity	Z = effective number of free electrons per atom
γ = density	

G. BORELIUS, E. RUDBERG, *Conference of Swedish National Committee for Physics 1957*

A. LUNDÉN, *Department of Physics, Chalmers Institute of Technology, Gothenburg*

Countercurrent electromigration in molten salts

Isotope enrichment by countercurrent electromigration has been studied in several molten salts, mainly halides. A comparison of the mass effects μ (relative difference in velocity of two ions divided by their relative difference in mass) indicates the existence of systematic relations, at least for cations in halide melts. By combining further measurements of mass effects with self-diffusion measurements in molten salts, it should be possible to increase our knowledge of the structure of molten salts.

KERSTIN LÖW, *Research Institute of National Defence, Stockholm*

Measurements on the Cs^{137} content of biological materials

The long-lived isotope Cs^{137} is one of the most important fission products from the point of view of retention in biological materials, where it is likely to follow potassium.

Some preliminary measurements on the Cs^{137} to K ratio in the bodies of living humans have been made using a γ -spectrometer consisting of a 5" dia $\times$ 4" NaI crystal and a multi-channel kick sorter. The ratios found were 30–50 pC Cs^{137} per g K.

Milk, which is supposed to be the main contributor of Cs^{137} , showed a level of 25 pC Cs^{137} per g of K. Experimental difficulties, in particular background problems, are discussed.

TH. A. J. MARIS and H. TYRÉN, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Theory of inelastic high energy scattering of nucleons on light nuclei

The two different excitation mechanisms leading to collective and single particle excitations are described. The expected angular distributions, asymmetries and polarizations are compared with the experimental results.

I. MARKLUND and T. LINDQVIST, *Department of Physics, University of Uppsala*

The influence of l -forbiddenness on magnetic dipole transitions in Tl^{203}

The angular correlation of the 400 keV–279 keV cascade in Tl^{203} has been measured. The correlation function has the form

$$w(\theta) = 1 - (0.205 \pm 0.005) \cos^2 \theta.$$

A comparison between the mixing ratio of the 400 keV transition ($d_{5/2} \rightarrow d_{3/2}$) and the mixing ratio of the 279 keV transition ($d_{3/2} \rightarrow s_{1/2}$) has been made. It turns out that the l -forbidden M 1 transition is retarded by a factor of 1.3×10^{-3} compared to the l -allowed one. The transition rates according to the single particle estimates by Moszkowski seem to represent the l -allowed transitions very well in this nucleus. A further conclusion from the result obtained is that the 400 keV transition in Tl^{203} is practically pure M 1 transition.

L. MINNHAGEN and L. STIGMARK, *Department of Physics, University of Lund*

Ionic spectra excited by large high-frequency pulses

Powerful high-frequency pulses have been generated by means of an installation consisting of a pulse generator, an oscillator, a frequency multiplier, a driver giving power to a final power amplifier, and a final resonance circuit. The final power amplifier contains a 25 kW, 12 kV water-cooled triode. The tank circuit and the final resonance circuit contain tubular capacitors to withstand the large high-frequency voltage. The inductance coil of the resonance circuit surrounds the quartz discharge tube. Frequency (usually about 9 MHz), pulse duration, and repetition frequency are adjustable. At 80 μ s pulse duration, 50 MHz repetition frequency and 20 kV anode voltage pulse power amounting to approximately 100 kW was transferred to the discharge tube, which, in the first experiments contained argon. At the lowest pulse power used, the spectra of singly and doubly ionized argon, A II and A III appeared. When the pulse power was increased, the A III lines gained intensity in relation to A II and new A III lines appeared. At the highest pulse power the A III intensity was very great and A IV lines also appeared. Thus the intensity variation of the lines with pulse power made it readily possible to distinguish the A IV, A III and A II spectra from one another.

H. MORINAGA, *Department of Physics, University of Lund*

Collective mode of excitation in light nuclei

Recently it has been proposed that the collective description gives successful explanation for $A = 19$ and $A = 25$ level schemes. It is pointed out that remarkably good agreement is obtained between observed spectrum of $A = 7$ and the calculated level schemes using the collective model. Also the collective description may apply to $A = 13$.

H. MORINAGA, S. A. E. JOHANSSON and E. MÖLLER, *Department of Physics, University of Lund*

Weak gamma rays from proton bombardment of F¹⁹

Gamma transition probabilities between lower excited states of O¹⁶ are of considerable theoretical interest, since more detailed descriptions of these levels have been proposed recently. These transitions were once looked for by Wilkinson with negative results. We have been using a large scintillation crystal which gives less background due to strong 6 MeV and 7 MeV gamma rays in the 1 MeV region. We have thereby achieved a considerable improvement over the former observation. With the same setup the capture gamma rays are studied more in detail. Those gamma rays give informations on the lower excited states of Ne²⁰, which were rather poorly known before. Preliminary results from this work are now presented.

H. P. MYERS, *Department of Physics, Atomic Energy Laboratory, Stockholm*

The variation of paramagnetic susceptibility and thermal expansion coefficient in copper-manganese alloys

Coefficients of thermal expansion were determined for a series of copper-manganese alloys, using a high temperature X-ray diffractometer. The expansion coefficient

shows a marked change as the manganese concentration is increased from 20 to 30 atomic %. This change is associated with similar variations in the paramagnetic and thermoelectric properties of these alloys and is attributed to a redistribution of the $3d$ electrons of the manganese from localized to delocalized state.

The significance of the apparent monovalence of manganese in these copper rich alloys is discussed in connection with the apparent valency of about 1.9 found by Haworth and Hume-Rothery in their study of the $\alpha/(\alpha + \beta)$ and $(\alpha + \beta)/\beta$ phase boundaries in Cu-Zn-Mn and Cu-Al-Mn alloys.

H. NEUHAUS, *Department of Physics, University of Stockholm*

Die Hyperfeinstruktur der optischen Bandenspektren

Das hohe Auflösungsvermögen des Hulthén-Immersionsgitters (Dispersion 4 mm/Å bei 5900 Å) hat es ermöglicht, bei einigen Molekülspektren (z.B. BiH, BiC, InH) eine Hyperfeinstruktur, Hfs, der Rotationslinien zu entdecken. Das Absorptionsspektrum des Indiumhydrids ist neulich studiert worden. Nur die $R(0)$, $Q(1)$ und $P(2)$ -Linien ($\tau_0 = 16905,00 \text{ cm}^{-1}$) des $(0-0)$, $^3\Pi-^1\Sigma$ -Überganges zeigen eine deutliche Hfs. Diese Linien sind in drei Hfs-Komponente aufgespalten. Die Abstände zwischen den Komponenten sind für $R(0)$ 0,109 und 0,113 cm^{-1} , für $Q(1)$ 0,132 und 0,061 cm^{-1} und für $P(2)$ 0,098 und 0,094 cm^{-1} . Die Breite der Linien nimmt schnell mit dem steigenden J -Wert ab. Die Hfs bei InH wird als eine magnetische Hfs interpretiert, die dadurch entsteht, dass eine magnetische Wechselwirkung zwischen Indiumkern und Elektronenhülle stattfindet. Zwei weitere Banden ($0-0$ bei 22018 cm^{-1} und $0-1$ bei 20593 cm^{-1}), welche dem Übergang $^1\Pi-^1\Sigma$ zugeschrieben werden können, sind entdeckt. Hier weisen die Linien keine Hfs auf.

F. MEDINA NICOLAU, *Department of Theoretical Physics, University of Copenhagen*

The method of the collision complex and the optical model of the nucleus

By use of the method of the collision complex for reactions with neutrons, the amplitude of the outgoing neutron wave caused by the decaying of the compound states in the entrance channel is derived. Averaging this amplitude over an energy interval that contains many compound nucleus resonances, one finds that, under certain circumstances, this average amplitude is equal to the amplitude of the neutron outgoing wave when scattered by a complex potential. Only the case of low energy neutrons is treated, and it is assumed that only the entrance channel is open.

A. NILSSON, *Nobel Institute of Physics, Stockholm*

A time-of-flight system for measurements of fast neutrons

The small cyclotron at the Nobel Institute in Stockholm now gives an extracted beam of 5–10 μA of 3.5 MeV (monoenergetic to better than 1 %) protons at a target 8 m away from the cyclotron. Due to the natural bunching mechanism of a cyclotron, the ions reach the target in short ($\approx 3 \cdot 10^{-9}$ s) bursts, recurrent at the cyclotron oscillator frequency, 12 MHz. The neutrons and γ -rays produced in the target are detected by a plastic scintillator, which has an efficiency of about 25 % for neutron energies

above 0.5 MeV. This detector triggers the sweep of a fast oscilloscope, giving an indication of the time of arrival of the particles. The starting time is indicated by a liquid scintillator, looking at part of the beam. The pulses from this scintillator are displayed at the oscilloscope screen. A photograph of the screen then gives a time-of-flight spectrum of the neutrons and γ -rays, which is easily converted into an energy spectrum. The energy resolution is 5–10 %.

— The system may be used to study 1) the angular distribution of neutrons from a reaction, 2) neutron scattering processes and 3) lifetimes of short-lived isomers.

R. NILSSON and S. BERGLUND, *Department of Physics, University of Uppsala*

A low inductance, high current condenser battery set-up for fusion experiments

A condenser battery with a capacity of 60 μF has been designed with extremely low inductance to give a wide range of variational possibilities as a current source for gas discharges. Among the different ways to achieve this that have been discussed, we have chosen a design with coaxial cables from the condensers giving great flexibility as to capacitance and mechanical arrangement. 120 condensers with a capacity of 0.5 μF each are connected to a pair of concentric rings, which thus constitute the poles of the battery. The inductance of the separate units including cable is 355 nH, and the inductance of the entire battery, as seen from the poles, is 4.5 nH. With a simple short-circuit arrangement the measured time of oscillation is 3.8 μs , giving a peak current over voltage of approx. 100 A/V. As the test voltage of the different parts is 60–65 kV, the battery should be capable of delivering 5 MA short circuit current at a rate $dI/dt = 10^{13}$ A/s.

The project has been accomplished in technical and financial cooperation with ASEA, in particular with the branch establishments of the company at Ludvika and Liljeholmen.

S. NILSSON, *Department of Physics, University of Uppsala*

Interactions of negative K^- -mesons

A stack of nuclear emulsions, 60 pellicles $4'' \times 7'' \times 600 \mu$, has been exposed to the partly separated K^- -meson beam at the Berkeley Bevatron. Beam momentum is (430 MeV)/ c . The stack is scanned across the beam at a residual range ≈ 7.5 cm of the K^- -particles. So far 58 stars at rest, 31 interactions in flight, 10 K_S^0 , 4 decays in flight and 2 stops have been found, all identified K^- -mesons. A preliminary analysis has been carried out.

S. NILSSON, *Department of Physics, University of Uppsala*

A decay of a negative τ^- .

A new mode of decay of a negative K meson has been found in nuclear emulsions, exposed to the partly separated K^- -meson beam at the Berkeley Bevatron.

The event is a decay in flight, consistent with the scheme

$$\tau^- \rightarrow \pi^- + \pi^0 + \pi^0$$

with $T_{\pi^-} = 52 \pm 2$ MeV in the center of mass system.

No blob or slow electron indicates a nuclear reaction.

Auger effect in copper

The precision method described in another paper¹ of this conference report can also be applied to the study of Auger spectra. So far the *KLL* and *KLM* spectra of Cu have been investigated. If one assumes extreme Russell-Saunders coupling for the *L* electrons, theory predicts six lines in the *KLL* Auger group. The same number of lines results if one assumes extreme *j-j* coupling. However, if the coupling is an intermediate one, which is most probable in the element copper, the expected number of lines in the *KLL* Auger group is ten. In the present investigation seven lines have been distinguished in this group. Their energies have been determined with an error of less than $\pm 2,5$ eV. The relative experimental energies are compared with theoretical calculations performed by Kennard and Ramberg.²

The lines of the *KLM* Auger group are not resolved but there are indications of at least five peaks, the energies of which are determined.

A beta-spectrometric determination of gamma-ray intensities in Pb^{206} with high resolution from a study of the photoelectric emission and an experimental method for a general correction for the angular dependence of the photoelectrons

The longitudinal angular distribution of photoelectrons has been measured over the whole angular range ($-\pi \leq \vartheta \leq \pi$) for three different gamma-ray energies. From the experimental curves it is possible to obtain relative photo-electric cross sections by integrating from $\vartheta = 0$ to $\vartheta = \vartheta_0$, where ϑ_0 is a limiting angle defined by the geometry of the experimental set-up. A comparison of the measured angular distributions has been made with theory.

The method has been applied to the decay of Bi^{206} Pb^{206} where the relative intensities of about 20 gamma-rays have been determined with a maximum resolution corresponding to 0.4 %. From the relative gamma-ray intensities and the relative K-conversion line intensities, internal conversion coefficients have been computed.

The results are compared with theoretical conversion coefficients of Sliv. Within the limits of error satisfactory agreement has been found.

The multipolarity assignments agree with the assignments given by Alburger and Pryce³, except in a few cases.

Fusion experiments at high current discharges in deuterium

A series of experiments on discharges in deuterium, using currents from about 100 kA up to the MA-range, are described. As a current source, condenser batteries of

¹ E. SOKOLOWSKI, C. NORDLING and K. SIEGBAHN (this conference).

² E. H. KENNARD and E. RAMBERG, *Phys. Rev.* **46**, 1040 (1934).

³ D. E. ALBURGER and M. H. L. PRYCE, *Phys. Rev.* **95**, 1482 (1954).

different types have been used and considerable work has been done on improving the condensers and designing a low inductance wiring of the battery. The final battery has a capacity of $60 \mu\text{F}$, a test voltage of 60 kV and a total inductance of only 5 nH, permitting a short-circuit current of the order of 5 MA. Details on the battery and the methods of measuring voltage and current are given in a separate paper by S. Berglund and R. Nilsson. Discharge tubes, capable of withstanding several hundreds of heavy discharges, have been designed. The pinch effect is studied mainly by observing dI/dt as a function of time during the discharge, but also by measuring the voltage variation across the discharge tube.

Neutron showers simultaneous to the pinch are observed by means of a scintillation counter. Activation of silver by the neutrons has also been registered. Neutron showers often appear twice or three times during a single discharge, and always simultaneous with a pinch. Systematic investigations have shown the neutron production to be very sensitive to the gas pressure and to other parameters such as dimensions etc.

INGRID OLSSON, *Department of Physics, University of Uppsala*

A C^{14} dating station using the CO_2 proportional counting method

The proportional method has been chosen since it is very suitable for the energy interval dealt with in C^{14} dating and because the method is convenient for routine work. The counter consists of carefully chosen materials and is very well shielded. The background has been reduced from about 300 c/min to 1 c/min. A heavy iron shield reduces the gamma-radiation from outside, and a set with Geiger counters in anticoincidence with the proportional counter eliminates the mesons in the cosmic radiation. We have 3 cm of mercury between the proportional counter and the Geiger counters. The contribution from the weak component of the cosmic radiation is reduced by the use of paraffin blocks with boric acid. The counter has only been tested for 3 atmospheres, but it is built to stand higher pressures.

P. O. M. OLSSON, *Department of Theoretical Physics, University of Stockholm*

Finite nuclear size influence on internal conversion coefficients

The simplification of using a point nucleus in calculations of the internal conversion coefficients may lead to serious errors. Recent extensive calculations by L. A. Sliv and M. A. Band show that the conversion coefficients are as much as 60 % lower than the point nucleus calculations of M. Rose for magnetic transitions, and as much as 20 % lower for electric transitions. The largest finite nuclear size corrections occur for M1 transitions and the highest electric multipole order considered (E5).

It seems reasonable to believe that a not negligible part of the above mentioned corrections depends on the nuclear structure; particularly so for transitions from metastable states, where the γ -ray matrix elements are attenuated. In fact, a model with arbitrary conversion rate is easily constructed. Similar thoughts are found in a paper by E. L. Church and J. Weneser.¹

If there is a nuclear structure dependence in the conversion coefficients they will

¹ E. L. CHURCH and J. WENESER, *Phys. Rev.* **104**, 1382 (1956).

not be the smooth functions of Z and of transition energy obtained by Sliv and Band. To what extent deviations from the Sliv-Band values may be expected is now being investigated theoretically.

R. PERSSON, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Measurements on control rods in an exponential assembly

The static behaviour of control rods has been investigated in our exponential assembly. The experimental results are found not to be consistent with the theory valid for a homogeneous reactor core. It seems necessary to apply a correction associated with the disturbance of the adjacent unit cells. Errors caused by introducing air and aluminium are also pointed out.

B. G. PETTERSSON, T. LINDQVIST and K. SIEGBAHN, *Department of Physics, University of Uppsala*

The internal Compton effect (ICE). An experimental determination of cross section and angular correlation

It is well known that there exist some fundamental effects where energy is transferred from a photon or excited nucleus to an electron. One usually discriminates between external and internal effect, respectively. Thus internal and external photo-, pair- and bremsstrahlung-effects are easily observable. The internal counterpart to the classical Compton effect has not yet been unambiguously demonstrated. The internal Compton effect is a nuclear transition in which there is a simultaneous ejection of a bound electron and emission of a photon. We have been able to single out the new effect in the presence of the other above mentioned effects in the case of Ba^{137} with the help of a newly constructed beta-gamma coincidence spectrometer. The cross section for photons in the 95 keV–125 keV energy band and at 90° between the electron and photon directions was determined to be $(1.87 \pm 0.27) \times 10^{-5}$ photons per conversion electron and unit solid angle. The corresponding theoretical value according to Spruch and Goertzel¹ is 1.86×10^{-5} . A very pronounced angular dependence was found. The cross section at 90° was six times larger than that at 180° , which is also in agreement with the theory.

B. E. RONNE, G. EKSPONG and S. JOHANSSON, *Department of Physics, University of Uppsala*

A determination of the mass of the antiproton by the analysis of an elastic P-P collision

During the work with our antiproton stack we have observed a collision between an antiproton and a proton. The proton stops after having travelled 0.3 cm. After a further 5.2 cm the antiproton gives a star in flight with 7 protons and 2 pions. The event is coplanar within the errors of measurement.

¹ L. SPRUCH and G. GOERTZEL, *Phys. Rev.* **94**, 1671 (1954).

From the kinematics of the event it is possible to determine the mass of the anti-proton.

From this and from 4 similar events observed at Berkeley we can now estimate a cross section for P-P scattering.

G. RUDSTAM, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Nuclear reactions initiated by high energy protons

Reactions initiated in medium weight atomic nuclei by fast protons have been studied. The formation cross sections of the spallation products have been determined, using chemical separations and radioactivity measurements. The cross sections vary regularly with the atomic number and mass number of the products. A theoretical calculation of the cross sections has also been performed, using a model in which the reaction is supposed to take place in two steps: first a nucleon cascade and afterwards particle evaporation from the excited nucleus left at the end of the cascade. This calculation yields results which agree satisfactorily with the experimental data.

A. E. SANDSTRÖM, *Department of Physics, University of Uppsala*

Cosmic ray measurements with an airborne neutron monitor

The intensity variation with geographic coordinates of the cosmic ray soft (nucleonic) component was measured by means of a small neutron pile monitor mounted in DC 7 C aircrafts. The route was from Stockholm across the North Pole, Fairbanks, Anchorage and Shemya to Tokyo and from there via Manila, Bangkok, Karachi, Athens, Rome, Geneva, Frankfurt a/M and Copenhagen back to Stockholm. The flights were concentrated to the days 16 to 19 February and 26 to 28 February, 1957. During these periods there were no single events. The concentration of the measurements to a short period diminished the effects of long period variations.

The result of the expedition was a continuous record of the relative intensity all around Europe and Asia. The "knees" in the latitude effect curves were determined at two longitudes 170° apart. Referred to conventional geomagnetic coordinates these two curves do not coincide. In the same way other features of the records show that the usual centred dipole model of the earth's magnetic field does not describe with a sufficiently high accuracy the field acting upon the cosmic ray primary particles. This discrepancy is in accordance with results from ship-borne monitors as found by Rose, Simpson and others.

P. O. SCHÖRLING and P. OHLIN, *Department of Physics, University of Uppsala*

X-ray flash Cu K spectrum

K-spectra of Fe, Ni, and Cu from an X-ray flash tube have been recorded photographically and compared with spectra from an ordinary X-ray tube. The Fe- K_{β_1} satellite was found to be definitely stronger in the flash spectrum than in the ordinary spectrum. In the Cu-K spectrum the same satellite appeared, though it does not exist in the ordinary spectrum. The Ni flash spectrum shows at least one K_{β_1} satellite, which is not visible in the ordinary spectrum.

A theoretical study of the conditions for ignition of an explosive by a heated filament

The heat transfer and the reaction yield have been studied in the case of a filament surrounded by a charge, which will suffer an exothermal reaction when heated. The filament is considered to be straight, of infinite length, and infinitely heat conducting; it is imagined to be kept at constant absolute temperature T_1 . It is assumed that the physical properties of the charge (density ρ , specific heat capacity c , heat conductivity γ) do not change in the reaction. It is further assumed that the reaction proceeds according to a monomolecular rate law. Under these conditions of cylindrical symmetry, what happens at any point in the charge will depend on the time t and on the space coordinate r only, where r represents the distance of the point from the filament axis. Let n denote that fraction of the original charge, at any point r and at any time t , which has not yet reacted, T standing for its absolute temperature. With q the heat of reaction per mass, B the activation energy pro mol and A a constant, characteristic of the reaction in question, the following equations are derived

$$\rho c \frac{\partial T}{\partial t} = -\rho q \frac{\partial n}{\partial t} + \lambda \left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} \right)$$

$$\frac{1}{n} \frac{\partial n}{\partial t} = -A e^{-\frac{B}{RT}}.$$

Boundary conditions are: for $t = 0$, $T = T_0$ and $n = 1$ everywhere in the charge; and, furthermore, on the filament for all times $t \geq 0$, $T \equiv T_1 > T_0$. The temperature in the charge, as a function of time for $t > 0$, and the minimum value of T_1 required to produce reaction throughout the entire charge (detonation) have been computed on the electronic machine BESK by G. Ehrling. The numerical data used in this computation correspond approximately to a charge of mercury fulminate. The results obtained should, with some modifications, be applicable to the case of so called "hot spots".

L.-E. SELIN, *Department of Physics, University of Stockholm*

Das Bandenspektrum des Vanadiumoxydes

In dem Spektrum des Vanadiumoxydes sind drei Bandensysteme bekannt. Das erste erstreckt sich vom violetten Gebiet bis in das rote, das zweite liegt im nahen ultraroten und das dritte im ultraroten Gebiet. Eine Rotationsanalyse einiger Banden des gelben Systems ist durchgeführt worden. Viele Störungen sind hier im oberen Zustand gefunden und analysiert worden. Die Existenz dieser zeigt, dass die Analysen richtig sein müssen.

L. SIMONS, *Department of Theoretical Physics, University of Helsingfors*

The inverse reactions $B^{11}(p,\gamma)C^{12}$ and $C^{12}(\gamma,p)B^{11}$

In order to obtain a conception of the common compound channels for the inverse reactions $B^{11}(p,\gamma)C^{12}$ and $C^{12}(\gamma,p)B^{11}$, the cross section for the pure inverted process

to the reaction $B^{11}(p,\gamma)C^{12}$ has been calculated according to the reciprocity theorem, i.e., the cross section for the distribution relating to orbital angular momentum of the protons that have occurred in $B^{11}(p,\gamma)C^{12}$ experiments, which distribution is unknown but can be considered, for equal energy, to be equal on the whole in all these experiments. The cross section obtained in this manner has been compared in the common energy range of about 2 MeV with the experimentally found cross section for the $C^{12}(\gamma,p)B^{11}$ reaction. It appears that the common channels comprised a considerable part of the experimental $B^{11}(p,\gamma)C^{12}$ process, but only a small part of the experimental $C^{12}(\gamma,p)B^{11}$ process. This is clearly connected with the unusually ample proton yield which has been obtained from the reaction in the vicinity of the "giant resonance" peak and which is considered to be due to the fact that quanta frequently react with single protons in the C^{12} nucleus, instead of with the entire nucleus. The previously stated spin and parity 2^+ for the 16.10, 18.3 and 19.2 MeV levels, and 1^- for the 17.22 MeV level of C^{12} are compatible with both inverse processes, but there is probably at least one further 1^- level among the recently discovered levels richer in energy, or among yet undiscovered resonance levels.

B. SJÖGREN, *Nobel Institute of Physics, Stockholm*

Angular distribution measurements on (d,p)-reactions II

* At $E_d = 800$ keV the angular distributions have been measured for four proton groups from $B^{10}(d,p)B^{11}$ (corresponding to the excited states 6.76, 6.81, 7.30 and 7.99 MeV of B^{11}), for two groups from $N^{14}(d,p)N^{15}$ (5.28 and 5.31 MeV) and for two groups from $O^{18}(d,p)O^{19}$ (ground state and 0.10 MeV). A comparison has been made with the Butler theory for deuteron stripping, and the finite mass of the target nucleus has thereby been allowed for. That theory in which e.g. Coulomb interaction is neglected has been used, since it is rather simple for numerical calculations. It is possible to draw some conclusions from the comparison, although the theory should not be a very good one for low deuteron energies.

N. G. SJÖSTRAND, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Measurements on reactor models using a pulsed neutron source

The concept "geometrical buckling" is connected both with the critical size of a reactor and with the rate of decay of the neutron density in a small moderator volume. With a small reactor model it is therefore possible to study some characteristics of a reactor which are often difficult to measure in full scale, or to calculate. Such model experiments have been made, using a pulsed neutron source to study the influence of strongly absorbing control rods on the reactivity of a reactor. Preliminary results from these experiments are given.

H. SLÄTIS, *Nobel Institute of Physics, Stockholm*

On the three permanent magnet beta-ray spectrometers of the Nobel Institute of Physics, Stockholm

In addition to the earlier described permanent magnet beta-ray spectrometer for photographic recording of conversion lines, two new semicircular permanent magnet

spectrometers of a simplified construction have been built. The new spectrometers and experiments with them are briefly described.

E. SMÅRS, *Department of Electronics, Royal Institute of Technology, Stockholm*

On the measurement of time-varying magnetic fields

In an accelerator of the synchrotron or betatron type a magnetic field is used which varies periodically with time. Since the magnet almost always is made with iron, the space distribution of the magnetic field is not constant during the cycle. This is due to remanent and eddy current fields, which play an important role at low fields, and to saturation effects at high fields.

To measure the space distribution of the magnetic flux density B and hence its gradient dB/dx and the variation thereof during the magnetic cycle, as well as to measure the absolute value of $(1/B)(dB/dx)$ and its variation with time, an accurate method has been developed. The method is a null method. It employs a single small search coil, when measuring B , or a twin coil with distance Δx , when measuring dB/dx . The signal from either of these is compared with the signal from a reference coil at a fixed position, and the difference is integrated in an electronic integration circuit. To determine the integration constants a technique with peaking strips is used.

The error when measuring relative values of B is less than $\pm 0.1\%$; when measuring dB/dx it is approximately $\pm 0.1\%$, and when measuring the absolute value of $(1/B)(dB/dx)$ (which is about 0.03 cm^{-1}) the error is approximately $\pm 0.2\%$.

E. SOKOŁOWSKI, C. NORDLING and K. SIEGBAHN, *Department of Physics, University of Uppsala*

Binding energies of internal shells in Cu, Cr and Zn studied by means of a new precision method

The K binding energies of Cu, Cr and Zn and the L_I binding energy of Cu have been studied. A thin evaporated layer (a few hundred Å) of the metal under investigation is irradiated with X-rays of definite wavelength (e.g. the Mo $K\alpha_1$ line). The energy of the photoelectrons ejected is measured with an iron-free, double-focussing β -spectrometer. By subtracting this energy from that of the incident X-radiation one obtains the absolute binding energy of the electronic shell under investigation.

The first element to be studied was copper. Here the K and L_I binding energies are found to be 8985.5 eV and 1100 eV respectively. These measurements were performed with the F -line of ThB as an energy standard. In order to avoid errors due to changes in geometry the ThB was collected electrostatically on a converter backing, after which a Cu layer was superimposed. The F -line and Cu photo-lines could then be measured in the same run.

In the subsequent measurements the K photo-line of copper is used for the calibration. In this case three samples are evaporated on a 6 cm long Al backing. The upper and lower samples are pure copper and the middle one is the element under investigation. These three converters can be irradiated successively by pushing them into the X-ray beam.

The greatest energy shift obtained between the upper and lower parts is about 1.5 eV.

In most cases it is much less. Such a shift is due to a slight divergence from the vertical orientation of the Al strip, and one can find the right value for the middle part by linear interpolation.

In this way the K binding energies of Zn and Cr have been measured and found to be 9665 ± 1 eV and 5997 ± 1.5 eV respectively, using the Mo $K\alpha_1$ radiation for the photo-electron production. A check was made on the binding energy of Zn by using an X-ray line of different energy, namely the $K\alpha_1$ line of Rh. This measurement gave exactly the same value of the K binding energy in Zn: 9665 ± 1 eV.

Preliminary experiments have furthermore been performed in order to search for "chemical" shifts in the binding energy of different internal shells. The results of these orientating experiments performed on chloride and oxide of copper and on Cu in brass are also discussed.

N. STARFELT and J. KOCKUM, *Department of Physics, University of Lund*

The response of a total absorption scintillation spectrometer to monoenergetic γ -rays

In the analysis of γ -ray pulse height distributions, obtained with scintillation spectrometers, knowledge of the response function of the spectrometer at different γ -ray energies is essential.

The pulse height distributions, produced by monoenergetic γ -rays in a 12.7 cm diameter by 10.2 cm long NaI(Tl) crystal, have been studied. At low energies, several radioactive isotopes suitable as γ -ray sources are available. At higher energies, γ -rays obtained from nuclear reactions have to be resorted to. The following reactions were used: $\text{Be}^9(\alpha, n, \gamma)\text{C}^{12}$ (γ -ray energy 4.43 MeV), $\text{F}^{19}(\text{p}, \alpha, \gamma)\text{O}^{16}$ (6.14 MeV), $\text{B}^{11}(\text{p}, \gamma)\text{C}^{12}$ (4.43, 11.7 MeV), $\text{Li}^9(\text{p}, \gamma)\text{Be}^8$ (14.7, 17.6 MeV). The α -particles were obtained from a Po α -ray source; the protons were accelerated in a van de Graaff generator.

Measurements were performed with cylindric lead collimators of diameters ranging from 2 to 17 cm. The pulse height distributions were corrected for neutron background, and for disturbing γ -ray lines, to give the response function of the spectrometer to monoenergetic γ -rays of energies 0.662, 1.28, 4.43, 6.14, 11.7, and 17.6 MeV.

The pulse height distribution produced in the NaI(Tl) crystal by neutrons from the Po-Be source was also studied by inserting lead absorbers of different thicknesses between the source and the crystal, to absorb the 4.43 MeV γ -rays.

R. STEDMAN, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Apparatus for slow neutron spectrometry at R 1

Time-of-flight apparatus for analysis of a slow-neutron spectrum is in operation. This consists essentially of a "slow chopper", which is open to a neutron beam for a short interval during each revolution, a detector, which responds to neutrons that have travelled a few metres beyond the chopper, and a time analyser, which sorts the detector pulses in time relative to a synchronising pulse from the chopper. The detector is a battery of 29 BF_3 proportional counters. The time analyser consists of a unit which produces a pulse train of a length corresponding to the time-of-flight of a particular detected neutron, together with the register section of a Philips 100-

channel pulse-height analyser, into which the pulse trains are fed. The uncertainty in the positions of the channel boundaries is $\pm 0.05 \mu\text{s}$; channel widths from 2 to $100 \mu\text{s}$ can be chosen. The chopper is primarily intended for analysis of spectra of inelastically scattered neutrons in the region $1\text{--}3 \text{ \AA}$, in experiments on crystal lattice vibrations. At 13000 rev/min the burst time is $30 \mu\text{s}$, which gives a resolution of $10 \mu\text{s/m}$ when the flight path is 3 m. The beam area is $4 \times 10 \text{ cm}^2$.

R. STOCKENDAL, T. NOVAKOV, M. SCHMORAK and B. JOHANSSON, *Nobel Institute of Physics, Stockholm*

Nuclear levels in Pb^{203} and Pb^{204}

The investigation of levels in Pb^{203} and Pb^{204} was started because of the general interest in the nuclei in the region of the "double magic" $^{126}\text{Pb}^{208}$. In earlier investigations the experimental level schemes of $^{82}\text{Pb}^{205}$, Pb^{206} and Pb^{209} have been successfully compared with the theoretical levels expected from the shell model. It is hoped that the investigation of the levels in Pb^{203} and Pb^{204} , which is not yet completed, will give further check to theory and lead to a better understanding of the level systematics in this region.

The isotopes were investigated by studying the decays of their bismuth parents. As Bi^{203} and Bi^{204} have about the same half-life ($\approx 12 \text{ h}$), the decays were distinguished by using Bi^{203} and Bi^{204} samples produced by bombarding radiogenic lead with protons of different energies. Furthermore, samples of Bi^{204} without any presence of Bi^{203} were produced by bombarding thallium with 38-MeV α -particles. Some investigations were also carried out on electromagnetically isotope-separated samples, using coincidence- and scintillation-spectrometer measurements.

Conversion spectra were studied in double-focusing spectrometers, a permanent magnet spectrometer and an intermediate-image β -spectrometer.

Positrons of energies around 740 keV and 1350 keV were found in the decay of Bi^{203} .

Electron-gamma coincidence measurements were performed with an intermediate-image β -spectrometer, adapted for the purpose with a NaI(Tl) crystal (for γ) and an anthracene crystal (for e^-). The resulting pulses were fed to a coincidence apparatus¹ with a 100-channel pulse-height-analyzer. The resolving time of the coincidence apparatus was $2\tau = 3 \times 10^{-8} \text{ s}$.

W. STOFFREGEN, *Ionosphere Observatory, Research Institute of National Defense, Uppsala*

The Uppsala Ionosphere Observatory

At Uppsala Ionosphere Observatory, a section of the Research Institute of National Defence, Stockholm, investigations of radio wave propagation by ionosphere reflections are made. The geographical situation near the auroral zone is the reason why radio propagation conditions in Sweden are quite variable. During the International Geophysical Year 1957–58 special efforts will be made to study the relation between ionospheric disturbances, variations in the earth magnetic field, solar radiation and aurora.

¹ B. JOHANSSON, this conference report, see above.

At the observatory instruments for ionospheric research and an all-sky aurora camera are now in operation. All these instruments were designed and manufactured at the observatory. The ionospheric recorders, or "Ionosonds", consist of a radio pulse transmitter and receiver, together with oscillograph units for photographic recording of the radio echoes. The ionosonds are operating automatically and make usually one record each hour. During each record the frequency of the ionosond changes continuously from 1.4 to 16 MHz.

Two new recorders, which are still under construction, have a wider frequency range, 0.33–22 MHz. It is important that transmitter and receiver are exactly tuned together during the frequency sweep. This tuning is achieved by using the super-heterodyne principle in the receiver as well as in the transmitter. The ionosonds are designed for *vertical soundings* of ionised layers of the ionosphere.

For study of the ionosphere at oblique incidence by means of backscatter, a rotating beam antenna is used. With this antenna ionosphere reflections up to 2000 km distance can be received.

The observatory is one of the more than hundred international ionospheric stations. Monthly bulletins containing ionospheric data are exchanged with these other stations.

Since January this year a secondary station is in action at Lycksele, approximately 500 km north of Uppsala. Six aurora cameras are operating between Uppsala and Tromsø. All together the observatory has manufactured twenty aurora cameras. Fourteen of these have been delivered to other European institutions. Thus 17 cameras will be in operation near and inside the northern auroral zone; the remaining three have been installed in the Antarctic.

The behaviour of the ionosphere during aurora is very complicated. During an intense aurora total fade-out of all radio communications through the auroral zone is often observed. This is due to the high absorption of radio waves in the lower regions of the ionosphere, somewhat below 100 km. On the other hand, periods with strong aurora may be associated with quite good radio reflections. These reflections are observed from sporadic layers overhead. Radio signals are even reflected directly from the aurora up to a distance of about 300 km. Some new results of these investigations are shown.

The observatory has its own prediction service. Radio forecasts are made each month. These forecasts are valid for a range of 3000 km around Sweden. In the future the observatory will supplement these monthly predictions with forecasts given for each day, correcting the monthly forecasts according to the actual sunspot activity and other changes of solar radiation.

Å. SVANHEDEN and H. TYRÉN, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Extraction and focusing of the proton beam of the Uppsala synchrocyclotron

The extraction system for the proton beam of the Uppsala synchrocyclotron is described. The non-linear regenerative method proposed by J. K. LeCouteur has been applied. An external beam of about 5×10^{10} protons per second has been obtained. The beam is brought through an evacuated tube into an experimental room, located at a distance of 16 m from the cyclotron. Here it can be focused to a spot of about 4 mm diameter by means of two sets of quadrupole magnet lenses of the strong focusing type. The energy of the protons is 185 MeV with a half width spread of about 1 MeV. Experiments have been performed in this beam since January 1956.

The cosmic ray photon and π^0 -meson energy spectra at 90000–100000 feet above sea-level

The photon-spectrum at 90000–100000 feet above sea-level and 64° – 65° geomagnetic latitude has been determined by means of the nuclear emulsion technique, the multiple scattering of the electron-pairs produced when the photons materialize in the emulsion being measured. Distorsion, noise, energy loss of the electrons, outscattering and materialization probability have been taken into account. The relation between the registered photon spectrum and the π^0 -meson production spectrum in the vicinity has been studied. The exponent obtained for the differential energy spectrum of the π^0 -mesons is 1.53 ± 0.16 in the total energy interval from 0.25 GeV to 3 GeV and 2.8 ± 0.4 for energies greater than 3 GeV. The errors are statistical standard errors. The last exponent may suffer from systematic errors due to distorsion, spurious scattering and imperfect scanning efficiency, errors which are difficult to estimate.

J. W. SWENSSON, *Department of Physics, University of Lund*

Spectra of doubly and trebly ionized titanium

The spectra of doubly and trebly ionized titanium have been photographed with a Jarrell-Ash, 21-foot grating spectrograph in the 1950 Å–10000 Å region by means of a condensed, hollow-cathode discharge. First, second and third-order spectra have been obtained, the dispersion in the first order corresponding to 5 Å/mm.

The light source consists of a pyrex bulb, 22 cm in diameter, containing a titanium anode and a cathode in the form of a thin walled titanium cylinder, 12 mm in diameter and 50 mm in length. This discharge tube, very similar to the one previously used by S. Glad, is filled with helium gas under low pressure (6–15 mm Hg) and connected to a 10 μ F condenser through a rotating spark gap. A full-wave rectifier is used to charge the condenser. When the installation is operating at 1500 to 1800 volts, a great number of sparks appear inside the hollow cathode and a luminous layer appears along the walls. The spectrum of this layer consists mainly of Ti I and Ti II lines, whereas Ti III and Ti IV lines appear in the spectrum of the central region of the cathode. Since the cathode is focused end-on on the slit of the spectrograph, a separation of the various stages of ionization is possible according to the shapes of the spectral lines.

E. TENERZ, *Department of Theoretical Physics, University of Uppsala*

On the calculation of lattice vibrations in KCl

The aim of this investigation was to estimate the distribution function of lattice vibrations at 0°K in KCl. Earlier Iona (1941) determined it from the elastic constants and the residual ray frequency, measured at room-temperature, using the classical Born-model. This computation has now been recalculated with new empirical constants, measured at 293°K. Since the residual ray frequency is not known at 0°K, the Born-model according to Iona cannot be used in the calculation of the distribution function at 0°K. Therefore we used a modified model, where the classical ionic

charge is replaced in the Coulomb-interaction by an effective charge, which Lundqvist (1955) studied in a quantum mechanical investigation. The specific heat c_v was computed from this distribution function. The agreement between the calculated values of c_v and the experimental values at temperatures around 20°K is not as good as what Iona obtained, but at very low temperatures the agreement is better.

G. TIBELL, H. TYRÉN and TH. A. J. MARIS, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

The scattering of 185 MeV protons on helium

The energy spectra of 185 MeV protons scattered on helium have been recorded with a magnetic analyser. Gaseous helium has been used as a target. Four angles were studied: 10.2°, 14.2°, 18.2° and 23.2°. A broad peak in the curve of cross section versus excitation energy of the residual nucleus was found at about 23 MeV.

P. A. TOVE, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Measurements on short lived α -activities produced in a synchrocyclotron

Short-lived α -activities induced by proton bombardment on heavy elements have been studied in the Gustaf Werner cyclotron, using a new method. Alpha particles emerging from thin targets are focused to a scintillation detector by means of a 180° magnetic spectrometer, formed by the magnetic field of the cyclotron. After a short cyclotron bombardment the decay of the α -activity is followed in an electronic time analyzer for each α -energy set by the magnetic spectrometer. Multiple traversals in the thin targets make the proton beam more efficient. The spectrometer resolution corresponds to a width of about 2 %. The half-lives that have been measured range from fractions of a second to several minutes. Results have been obtained from bombardments of thorium, uranium and radium targets.

H. TYRÉN and TH. A. J. MARIS, *Gustaf Werner Institute for Nuclear Chemistry, Uppsala*

Elastic and inelastic scattering of 185 MeV protons on some light nuclei

Elastic and inelastic scattering of 185 MeV protons on carbon, oxygen and calcium has been studied using the 185 MeV proton beam of the Uppsala synchrocyclotron.

The energy spectra of the scattered protons are analysed by means of a magnetic spectrometer, which can be pivoted around the scattering center. The energy resolution of the system corresponds to a width of 1 %. Clearly separated levels are found for which differential cross sections and angular distributions are given.

J. UHLER and T. ALVÄGER, *Nobel Institute of Physics, Stockholm*

Reconstruction of the isotope separator at the Nobel Institute of Physics

At the Nobel Institute an electromagnetic isotope separator has been working since 1948. Most separated material has been radioactive and used for nuclear

spectroscopy measurements. Such work in the lead region emphasized the importance of better resolving power. Experimentally it was found that the resolution could be increased by using the magnet as a sector field magnet. The separator has therefore been reconstructed in order to fulfil the requirements of a sector field magnet. A new ion source for solid substances and new ion optic systems have been installed. Furthermore, a vibrating probe is used for measuring the intensity distribution in the beam. A resolving power of about 1500 has been obtained with $5\text{ }\mu\text{A}$ xenon ions. "Over all efficiencies" as high as about 7 % have been obtained for lead ions. A typical example of the usefulness of the increased resolving power is the separation of 12 h Bi^{203} and 13 h Bi^{204} , reported by R. Stockendal at this conference. The impurity in each of these samples was less than 1 %. The separated samples were used both for measurements of the electron spectra and for electron-gamma coincidence measurements in a β -spectrometer.

U. UHLHORN, *Department of Theoretical Physics, University of Stockholm*

Propagation of electromagnetic waves through an inhomogeneous plasma

The properties of an inhomogeneous plasma are examined on the basis of a stochastic model for the interaction between electrons and molecules. The result is applied to the propagation of electromagnetic waves through a medium with electron density dependent on a single recti-linear coordinate only, and in the presence of an exterior magnetic field, which causes an anisotropy of the medium. The propagation is determined by a system of three coupled ordinary differential equations of the second order. It is shown that for very general choices of the electron density function exact expressions for transmission, reflection, and absorption coefficients may be obtained. The result is applicable to the propagation of radio waves through the ionosphere.

S. WAHLBORN, *Department of Theoretical Physics, Royal Institute of Technology, Stockholm*

Theoretical investigation of energy levels in some Bi-isotopes

With the aid of shell model calculations one may often be more definite about the assignments of levels in experimental decay schemes, as in the case of Arbmán's results for Bi^{206} and Bi^{207} . A theoretical investigation has been made of the energy levels in the neutron deficient Bi-isotopes Bi^{206} , Bi^{207} , and Bi^{208} . The basic assumptions are essentially the same as those used by Pryce for the corresponding Pb isotopes. Some striking features appearing from the theoretical treatment are the large level density implied by the shell model, and the strong effect of configuration mixing. The absence of most of the predicted levels in the experimental material may be satisfactorily explained by selection rules and by the specific mode of obtaining the experimental levels.

T. WESTERMARK, *Department of Physical Chemistry, Royal Institute of Technology, Stockholm*

Experimental devices for energy loss studies of electrons from a 5 MeV betatron

A 5 MeV betatron, built by O. Wernholm and E. Smårs of the Department of Electronics at this Institute, has been transferred to our laboratory for energy loss and

radiation chemistry studies. A double-focusing magnetic electron spectrometer has been constructed (90° sector type, radius 25 cm, resolution corresponding to a width of about 0.2 %) for energy measurement purposes. An electrostatic method making use of line widths of internal conversion electrons, has been developed for calibration purposes, as well as for energy loss studies. It has been found that the energy distribution for the betatron electrons can be made narrow if the phase angle of the ejection is large. Half-widths of 0.25 % on the momentum scale have been attained; this will possibly be improved further. A certain energy instability is still present.

Energy loss and straggling measurements are made by means of a xy-recorder, which displays the primary line as well as the energy loss spectrum after passage through thin sheets of matter.

H. WILHELMSSON, *Department of Theoretical Physics, University of Lund*

The coupling between polarized collective and single particle motions in the nuclear photoeffect

Two different approaches to the problem of the nuclear photoeffect have attracted considerable interest. One of these assumes that there is a polarized collective excitation of the nucleus caused by the incident photon, whereas the other considers the nuclear photoeffect as a single particle process. It is the purpose of the present study to try a description of the nuclear photoeffect which combines features of these two approaches. This is achieved by considering the coupling between the polarized collective oscillations and the motion of an individual nucleon. The coupling is assumed to originate from the time dependent local asymmetry between neutron and proton densities in the nucleus during the photo-process.

H. WILHELMSSON and MARGITA NILSSON, *Department of Theoretical Physics, University of Lund*

An alpha particle model for the nuclear photodisintegration of O^{16}

The photonuclear effect in O^{16} is studied theoretically for the case of one emitted nucleon. The giant resonance is described with the aid of a simple model, which assumes that in the O^{16} nucleus only four nucleons, forming an alpha particle, are affected by the γ -ray. The alpha particle is assumed to be moving in a static collective potential from the other nucleons, these being undisturbed during the photodisintegration process. Gaussian wave functions are used. The results obtained are not in disagreement with recent experimental information.

T. VÄNNGÅRD and P. O. KINELL, *Department of Physics, University of Uppsala*

Hyperfine structure in electron spin resonance spectrum of polyphenyls

Hyperfine interaction with protons has been observed in negative ions of polyphenyls. These ions are obtained when sodium in vacuum reacts with the phenyls in a 10^{-3} M solution in tetrahydrofuran. The spectrum of biphenyl (which has been reported earlier) is consistent with a spin density of 0.010 at each of the 4.4' protons,

0.005 at the 2.2' protons and less than 0.002 at the 3.3' protons. The spectrum of m-terphenyl is complicated—more than 60 lines with a total splitting of about 15 gauss—while the spectrum of o-terphenyl is less complex (probably 9 lines). p-terphenyl in a 10^{-3} M solution has not shown any hyperfine structure.

F. ÅKERHIEM, C.-E. WIKDAHL and K. EKBERG, *Department of Physics, Atomic Energy Laboratory, Stockholm*

Measurements of the neutron flux distribution in a reactor lattice cell

Two series of experiments have been carried out. In the first a cylindrical aluminum container, with a fuel element of natural uranium and heavy water, was lowered into the central channel of the reactor. In the second a larger aluminium container, with several fuel elements of natural uranium or uranium oxide and heavy water, was placed in the thermal column of the reactor. In the first case the disadvantage factor for the fuel alone can be determined, in the second the disadvantage factor for both fuel and moderator.

As neutron detector foils or wires of copper were used. These passed through narrow slits or holes in the fuel element, perpendicular to its axis. The resulting radioactivity was measured with a GM-counter or a scintillation counter. To obtain good resolution along the foil or wire only the β activity was measured, the inevitable γ activity being measured separately and subtracted. The influence of different thickness of the foil has been investigated.

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